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IDA GROUND-AIR MODEL I (IDAGAM I)

Volume 3: Detailed Description of Selected Portions

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October 1974

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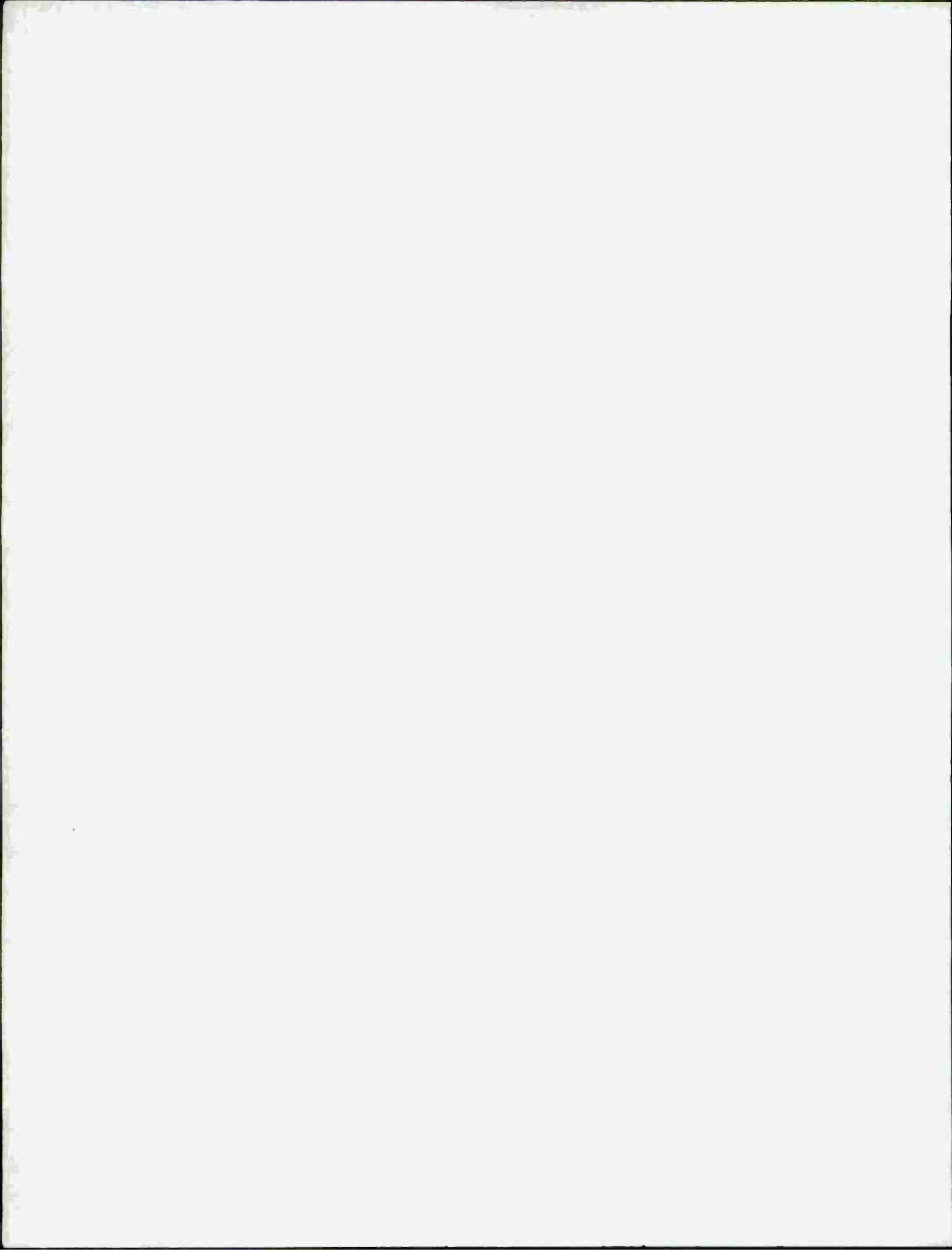Mary J. Hutzler
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The IDA Ground-Air Model I (IDAGAM I) is a deterministic, fully-automated, theater-level model of non-nuclear combat between two opposing forces. The report consists of five volumes, as follows: (1) Comprehensive Description, (2) Definitions of Variables, (3) Detailed Description of Selected Portions, (4) Documentation, and (5) Testing (U) (SECRET).

FOREWORD

IDAGAM I is a deterministic, fully automated model of non-nuclear combat between two opposing forces. The purpose of this report is to describe and document IDAGAM I. The report consists of five volumes, the contents of which are summarized as follows:

Volume 1 - Comprehensive Description

      I.   LEVEL OF DETAIL OF IDAGAM I

     II.   DESCRIPTION OF IDAGAM I

    III.   LIMITATIONS OF IDAGAM I AND SUGGESTIONS FOR FURTHER RESEARCH

      REFERENCES

Volume 2 - Definitions of Variables

      I.   PROGRAM, OVERLAYS, AND SUBROUTINES

     II.   DEFINITIONS OF VARIABLES

Volume 3 - Detailed Description of Selected Portions

      I.   MAXIMUM NUMBER OF RESOURCES AND OTHER QUANTITIES THAT CAN BE PLAYED

     II.   THE AIR-COMBAT MODEL

    III.   THE GROUND-COMBAT MODEL

    IV.   THE THEATER-CONTROL MODEL

     V.   THEATER CONTROL AT TIME ZERO

    VI.   GEOGRAPHY

Volume 4 - Documentation

Volume 5 - Testing

Volumes 1, 2, 3, and 4 are Unclassified; Volume 5 is Secret.

Since it would be much too unwieldy to include a copy of the code of the IDAGAM I computer program in this report, no such copy is included here. Copies of this code on appropriate media (tape, cards, etc.) can be obtained directly from the Institute for Defense Analyses.

CONTENTS OF VOLUME 3

FIGURES

INTRODUCTION

This volume gives a detailed description of selected portions of IDAGAM I in the same mnemonic notation as used by the IDAGAM I computer program. This notation is defined in Volume 2 and, in general, the definitions will not be repeated here. Accordingly, to read this volume, it is necessary to have a copy of Volume 2 at hand. Also, though this volume will discuss details, it will not attempt to provide an over-all description of IDAGAM I. Such a description is given in Volume 1, and this volume is written under the assumption that the reader is thoroughly familiar with Volume 1. Frequently we will refer to Volume 1 for certain explanations and formulas instead of repeating those explanations or formulas here.

Chapter I

MAXIMUM NUMBER OF RESOURCES AND
OTHER QUANTITIES THAT CAN BE PLAYED

A. THREE TYPES OF VARIABLES THAT REPRESENT PHYSICAL QUANTITIES

1. A Discussion of These Types

The variables representing physical quantities played in
IDAGAM I can be put into three categories--namely,

(1) Those variables whose maximum sizes are virtually
unlimited (i.e., they are limited only by the
largest numerical value that the computer being
used can hold).

(2) Those variables whose maximum sizes are limited only
by dimension statements in the computer program (and
so these maximum sizes can easily be increased or
decreased by changing these dimension statements).

(3) Those variables whose maximum sizes are fixed.

An example of the first type of variable is the number of
weapons of a particular type at a particular location. For in-
stance, the maximum number of tanks in a division is virtually
unlimited. (It should be emphasized here that we are addressing
only computer limitations, not logical limitations. The logic of
IDAGAM I limits the number of tanks in a division to the num-
ber called for by the TOE of the division.) A list of these
variables, whose maximum size is virtually unlimited, is given
in Section A.2 (below).

An example of the second type of variable is the number
of different types of Blue weapons that can be played. The
computer needs to reserve space for the number of weapons of
each type--for each variable that is a function of weapon type.
Thus, the number of reserved spaces in the computer depends,

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in part, on the maximum number of different types of weapons that can be played. The numbers of reserved spaces are determined by dimension statements in the computer program. Accordingly, to change the maximum number of Blue weapon types that can be played (or of any other variable of the second type), all that is necessary is to change the appropriate dimension statements.

Since these dimension statements reserve space in the computer, the size of the dimension statements, taken together, is limited by the size of the computer being used. But a user of IDAGAM I can adjust the dimension statements to meet his particular needs, bounded only by the overall size of the model and the size of his computer. For example, a user can play relatively more weapon types if he is willing to play fewer division types or a fewer number of sectors--and vice versa. Some examples of this structure are given in Section B of this chapter. A list of the variables whose maximum size is limited by dimension statements is given in Subsection 2.b (below).[1]

Examples of the third type of variable (those variables whose maximum size is fixed) are the number of different types of people in divisions (this must be 3 or less), and the number of different types of missions for aircraft (this must be 12 or less). It is possible to play these variables at less than their maximum size; but to do so, it is necessary to enter "zeros" in appropriate inputs, and so no computer space is saved by playing these variables at less than their maximums. A list of variables whose maximum size is fixed is given in Subsection 2.c (below).

---

[1] It should be noted that the dimension statements give only the maximum size of the variables. If a certain set of dimension statements fit into the computer, and if it is desired to play a smaller size for certain variables than given by these statements, then it can be done without entering "zeros" to fill up the rest of the storage spaces.

2. A List Of Variables According to These Types

a. Variables Whose Sizes Are Virtually Unlimited

The following is a list of variables whose sizes are virtually unlimited:[1]

(1) The number of people of any type in any location--i.e.,

TPBD(KBP,KBD)	TPRD(KRP,KRD)
BPDS(KBP,KBD,J)	RPDS(KRP,KRD,J)
BPDR(KBP,KBD,IB)	RPDR(KRP,KRD,IR)
BPDZ(KBP,KBD)	RPDZ(KRP,KRD)
BRPZ	RRPZ
BSPZ	RSPZ

(2) The number of weapons of any type in any location--i.e.,

TWBD(KBW,KBD)	TWRD(KRW,KRD)
BWDS(KBW,KBD,J)	RWDS(KRW,KRD,J)
BWDR(KBW,KBD,IB)	RWDR(KRW,KRD,IR)
BWDZ(KBW,KBD)	RWDZ(KRW,KRD)
BRWZ(KBW)	RRWZ(KRW)

(3) The number of divisions of any type in any location--i.e.,

NBDS(J)	NRDS(J)
NBDR(IB)	NRDR(IR)
NBDZ	NRDZ

(4) The number of aircraft of any type on any airbase--i.e.,

BAFR(KBA,IB)	RAFR(KRA,IR)
BARR(KBA,IB)	RARR(KRA,IR)
BAZ(KBA)	RAZ(KRA)

(5) The number of shelters at each location of shelters--i.e.,

BSARF(IB,IFPBS)	RSARF(IR,IFPRS)

(6) The number of SAMs and AAA defending each airbase[2] and the number of SAMs in theater--i.e.,

---

[1]Again, we note that this limitation of size refers only to computer limitations. The size of any of these variables can be limited by the logic of the model.

[2]The maximum number of SAMs and AAA in divisions is also virtually unlimited, as these are two of the types of weapons covered under item (2), above.

```
          BSAMFR(IB)              RSAMFR(IR)
          BSAMRR(IB)              RSAMRR(IR)
          BSAMZ                   RSAMZ
          BAGFR(IB)               RAGFR(IR)
          BAGRR(IB)               RAGRR(IR)
          BAGZ                    RAGZ
          TBSAM                   TRSAM
```

(7) The number of supplies in any location--i.e.,

```
          BGSS(J)                 RGSS(J)
          BGSR(IB)                RGSR(IR)
          BGSRUR(IB)              RGSRUR(IR)
          BGSZ                    RGSZ
          BGSZUZ                  RGSZUZ
```

In addition to these variables, the number of time periods to be played by the model (NTPP) is virtually unlimited by the size of the computer. However, this variable, unlike the variables above, increases running time as it is increased; and, thus, it is limited by running-time restrictions.

b. Variables Whose Sizes Are Limited by Dimension Statements

The following is a list of variables whose sizes are limited only by computer dimension statements:

(1) The number of different types of weapons--i.e.,

          NKBW   NKRW

(2) The number of different types of divisions--i.e.,

          NKBD   NKRD

(3) The number of days required for an individual per-
    sonnel replacement to reach full effectiveness--i.e.,

          NLEB   NLER

(4) The number of different types of aircraft--i.e.,

          NKBA   NKRA

(5) The number of different types of air munitions--i.e.,

          NKBAM   NKRAM

(6) The number of different locations for aircraft
    shelters--i.e.,

          NIFPBS   NIFPRS

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(7) The number of sectors--i.e.,

NJ

(8) The number of regions--i.e.,

NIB   NIR

(9) The number of intervals in the sector with the
maximum number of intervals--i.e.,

NIMAX

(10) The number of different types of terrain--i.e.,

NKT

(11) The number of intervals in which the desired COMMZ
reserve level can differ--i.e.,

NIBRL   NIRRL

In addition to these variables, all input piecewise linear
functions used by IDAGAM I are limited by the maximum number of
linear segments that these functions can have. For each such
function, this maximum number of linear segments is determined
by computer dimension statements. Thus, the numbers of linear
segments in piecewise linear functions are also variables
whose sizes are limited only by computer dimension statements.

As an example, suppose that all variables that are
functions of Blue weapons by type are dimensioned to hold 10
different types of Blue weapons. Then NKBW can be any integer
from 1 through 10, but it cannot exceed 10.

c. Variables Whose Sizes Are Fixed

The following is a list of variables whose sizes are fixed
by the IDAGAM I computer program:

(1) The number of different types of people in divisions
accounted for in IDAGAM I is exactly 3 for each side.
(Relatively minor changes in the computer program
could reduce this to 1 type of people for each side,
if this is desired.) In particular, the inputs NKBP
and NKRP must always be set equal to 3.

(2) IDAGAM I plays exactly 1 COMMZ for each side and
accounts for exactly 1 type of theater-support people
in the COMMZ.

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(3) IDAGAM I plays exactly 1 type of supplies for each side (other than missiles for SAM systems, which are, in a sense, supplies for SAM systems).

(4) IDAGAM I plays exactly 1 type of SAM system, 1 type of missile for these systems, and 1 type of AAA for each side. (If desired, a second type of SAM system can be played by using the space reserved for AAA; appropriate parameters for this second type of missile system would be input in place of the corresponding parameters for AAA. The limitations imposed on this second type of missile system would be that it must be short-range-- i.e., it cannot kill enemy aircraft that do not attack in its location, and it would not use up the supply of the missiles that the first type of SAM system uses.)

(5) IDAGAM I plays at most 2 notional airbases per region and one notional airbase in the COMMZ for each side. Thus, the maximum number of airbases is not "in-dependently" fixed (it can be increased by increasing the number of regions), but once the number of regions is fixed the number of airbases is fixed.

(6) IDAGAM I plays for each side exactly 1 type of shelter, which is assumed to accommodate all types of aircraft on that side.

(7) IDAGAM I plays at most 12 types of missions for each side (as described in Volume 1 of this report).

(8) IDAGAM I plays at most 5 general types of postures. (This means that NKP must always be less than or equal to 4, with the remaining type of posture being a holding posture.) Under some restrictions more types of postures could be played, but these would be subdivisions of the 5 general types now played.

(9) IDAGAM I assumes that replacements, reserves, and supplies can move overnight to their new locations (i.e., they move between time periods and arrive at their new locations at the beginning of the next time period). Thus, the "speed of movement" is fixed in IDAGAM I.

B.   TEST-CASE MAXIMUMS AND OTHER EXAMPLES

When running IDAGAM I on a particular computer, there are no options available to the user concerning the maximum size of either the first or third types of variables. However, the maximum sizes for the second type of variables can be set at various levels, and we will discuss in this section three

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examples of how this might be done. All three examples fit into the Control Data Corporation (CDC) 6400 computer used at IDA, with some core space left over.

1. Test-Case Maximums

In the testing of IDAGAM I (described in Volume 5), the computer-dimensioned maximums were chosen such that they covered a reasonable level of detail for modeling a conventional war in Europe. A list of variables whose maximums are determined by computer dimensions is given in Figure 1 (these variables are in the same order as in Section A.2.b, above). Next to each variable is the maximum value that the variable could assume in the testing, and next to that is the value that was actually used (these values were not changed in the testing).

2. An Example That Increases the Maximum Number of Weapon Types

As is evident from Figure 1, the test-case data do not use all the space set aside for data by the test-case maximum. By reducing the maximum values to the actual values, more space could be made available in the computer. This space could be used to increase the maximum values that are felt to be too constrained.

For instance, it may be desired to play more than 10 different types of weapons for each side. In the example described in Figure 2, the maximum values of each of the variables were reduced to the actual value for that variable in the test case; and the maximum number of different types of weapons on each side was increased to 15. Thus, if it is desired to play up to 15 different types of weapons on each side and use the test-case actual values for the rest of the maximums, it can be done on a CDC 6400 computer.

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Variable	Maximum Value	Actual Value
NKBW	10	10
NKRW	10	10
NKBD	6	4
NKRD	6	4
NLEB	5	4
NLER	5	4
NKBA	8	4
NKRA	8	3
NKBAM	10	9
NKRAM	10	5
NIFPBS	10	10
NIFPRS	10	10
NJ	10	7
NIB	4	2
NIR	4	3
NIMAX	15	15
NKT	4	3
NIBRL	8	8
NIRRL	8	8
End points for piecewise linear functions	8	various

Figure 1.   TEST-CASE MAXIMUMS AND ACTUAL VALUES
FOR VARIABLES WHOSE SIZES ARE LIMITED
BY DIMENSION STATEMENTS

Variable	Maximum Value
NKBW	15
NKRW	15
NKBD	4
NKRD	4
NLEB	4
NLER	4
NKBA	4
NKRA	3
NKBAM	9
NKRAM	5
NIFPBS	10
NIFPRS	10
NJ	7
NIB	2
NIR	3
NIMAX	15
NKT	3
NIBRL	8
NIRRL	8
Endpoints for piece-wise linear functions	8

Figure 2. MAXIMUM VALUES FOR AN EXAMPLE
THAT INCREASES THE NUMBER OF
WEAPON TYPES PLAYED

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3. An Example That Increases the Maximum Number of Division Types

In Section C of this chapter, we will describe a method to use IDAGAM I to play actual (rather than notional) divisions. This method requires greatly increasing the number of different types of divisions; and so, if the model is to fit on a computer of the same size, the maximums for the other variables must be reduced. We attempted to fit 36 types of Blue divisions, 95 types of Red divisions, and 7 sectors into the CDC 6400 computer, which required that the maximums of almost all other variables be reduced to 1. In addition, we had to assume that the number of kinds of postures was 2 instead of 5 and that the number of kinds of people in divisions (Blue and Red) was 1 instead of 3. Since NIMAX = 1, there can be only two postures: normal attack/defense and holding. In order to play NKBP = NKRP = 1, some minor programming changes must be made; but they could easily be made if it were desired to play actual (rather than notional) divisions.

The maximums for this example are given in Figure 3. If fewer sectors are to be played, the maximums of some of the other variables can be increased.

The basic reason that playing this many different types of divisions requires such a drastic reduction in the maximums for other variables is that, in addition to the inputs, many working variables are indexed to division type for both Blue and Red. This indexing causes no problem when a few notional types of divisions are being played and makes the program easier to read. However, if actual divisions are to to be played on a regular basis, changing these working variables could increase the space available in the computer. (These changes could include using one variable for both Blue and Red and doing computations within "DO loops" over type of divisions.)

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Variable	Maximum Value
NKBW	1
NKRW	1
NKBD	36
NKRD	95
NLEB	1
NLER	1
NKBA	1
NKRA	1
NKBAM	1
NKRAM	1
NIFPBS	10
NIFPRS	10
NJ	7
NIB	1
NIR	1
NIMAX	1
NKT	1
NIBRL	1
NIRRL	1
Endpoints for piece-wise linear functions	8

Figure 3.   MAXIMUM VALUES FOR AN EXAMPLE
            THAT INCREASES THE NUMBER OF
            DIVISION TYPES PLAYED

C. UNITS

1. Actual Divisions or Notional Divisions

By stating that a model plays "notional divisions by type," we mean that the model cannot distinguish a division of a certain type in a certain location from another division of the same type in the same location (but it can distinguish divisions of different types in the same location or divisions of the same type in different locations). Thus, a model that plays notional divisions cannot say, for example, that one division in a sector is at 100-percent strength while another division with the same TOE in the same sector is at 50-percent strength. It must say that the two divisions are at an average of 75-percent strength. By saying that a model plays "actual divisions by type," we mean that it can distinguish a division of a certain type in a certain location from another division of.the same type in the same location.

As stated in Volume 1, IDAGAM I was designed to play notional divisions by type; but it can be used, under certain restrictions, to play actual divisions by type. The way to play actual divisions is as follows: The maximum number of different types of divisions on a side would be increased to actual number of divisions that that side could have in the theater. Then each division would be treated as a unique type of division (and so there would be at most 1 division of each type in the theater). For example, if a side had 15 infantry divisions and 15 armored divisions, then the 1st Infantry Division would be the only type-1 division, the 2nd Infantry Division would be the only type-2 division--and so on, to the 15th Armored Division, which would be the only division of type 30.

This method is quite flexible, in that each division can have its own modified TOE (MTOE), relative movement rate, re-organization rate, etc. The limitation is that this method

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takes up very much computer space to play a reasonable number of divisions. So, unless one has an extremely large computer, it is necessary to reduce the maximums of other variables in order to use this method--which is what we did in the last example of the previous section.

2.   Divisions, Brigades, or Battalions

As described in Volume 1, IDAGAM I can play units of any size and units of various sizes simultaneously, provided that no unit is part of another unit that is being played. If actual units are to be played, then those units might have to be division-sized units. (For example, there would be too many battalions in the theater to play each battalion as a separate type of unit.) But if notional units are to be played, then IDAGAM I can easily be used to play any sizes of units.

An average in playing battalion-sized units, for example, is as follows: Suppose a region consisted of 2 sectors, and suppose that the side wanted to put one-third of its forces in reserve in the region and one-third of its forces in each sector. If the side had a total of 4 divisions available, then this allocation of forces could be achieved only very approximately. But if each division consisted of 9 battalions and battalion-sized units were being played, then 12 battalions could be assigned to each location and the allocations could be achieved exactly. However, it should be noted that playing smaller-sized units does not increase the basic level of detail of the model (as described in Volume 1), except that the model would be playing more, smaller units instead of fewer, larger ones.

D.   TIME PERIODS

As stated in Volume 1, there is no formal limitation in IDAGAM I on the length of the time periods played. Since

IDAGAM I can easily play time periods whose length is one day
(24 hours), there is no general reason why time periods longer
than one day should be played. The limitations of playing time
periods shorter than one day are as follows: First, there is
no automatic way for IDAGAM I to distinguish daylight from dark-
ness, and such a distinction would be an important part of
playing periods shorter than 24 hours.[1] Second, units, replace-
ments and supplies are assumed to be able to move between time
periods (i.e., overnight for one-day time periods) and arrive
at their new locations at the beginning of the next time period.
For a one-day time period, this assumption may not be a bad
approximation; but for time periods shorter than one day it
may be too strong.

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[1]The distinction between daylight and darkness could be "averaged
out" by playing 12-hour periods, with each period having the
same amount of daylight.

Chapter II

THE AIR-COMBAT MODEL

In Volume 1, the air-combat model of IDAGAM I was described
in terms of seven steps. With the third step broken into two
parts, the eight sections of this chapter correspond in order
to those steps.

To read this chapter, we recommend having available a copy
of the variable definitions (Volume 2) and a copy of the IDAGAM
I computer program. The steps in this chapter should be read
simultaneously with reading the corresponding steps in the com-
puter program. Since the variables will not be defined here, a
copy of Volume 2 is necessary.

A. SHELTERS

The first step in the air-combat model is to compute the
number of shelters associated with each airbase and the number
of shelters overrun by the enemy. This computation is necessary
because shelters are assumed to be in fixed positions, while
the notional airbases are assumed to be certain distances from
the FEBA, which moves from day to day. (Specifically, IDAGAM I
assumes that if some aircraft in a region are using a particular
actual airbase and if that airbase becomes too close or too far
away from the FEBA, then these aircraft move to another actual
airbase. So, in a sense, the notional airbases move with the
FEBA.)

We will describe how the computations are made for Blue;
similar computations are made for Red. These computations
are all made in part 1 of the air-combat model (AC1).

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The fixed locations of the Blue shelters are given by the input variable FPBS(IFPBS). The term IFPBS gives the location of the shelters within the regions. Since shelters are in regions and since FEBA positions can vary sector by sector, an assumption has to be made in order to calculate distance from the shelter to the FEBA. IDAGAM I calculates this distance by selecting the sector of maximum penetration in the region and calculating the distance from the shelter location, FPBS(IFPBS), to the FEBA position in this sector, which we denote by FPS. (Note that FPS is implicitly a function of IB.) The reason that the sector of maximum penetration was chosen (rather than minimum penetration or some sort of average FEBA position) is that, once certain criteria are satisfied (as explained in Section C of this chapter), the defender's CAS aircraft attack in the sector of maximum penetration and the attacker's CAS aircraft attack there also, if MCSMAB = 1. (It would be a very minor change in the computer program to compute FPS based on some other consideration, such as minimum penetration or average FEBA position.)

The variable BSARF(IB,IFPBS) gives the number of Blue shelters in region IB at the location FPBS(IFPBS). If these shelters have been overrun by Red (i.e., if FPBS(IFPBS) $\leq$ FPS), then the shelters are assumed to be destroyed (BSARF(IB,IFPBS) is set equal to 0.0). If these shelters are not overrun and are within DSB of FPS (i.e., if FPS < FPBS(IFPBS) $\leq$ FPS + DSB), then the shelters are assumed to be too close to the FEBA to be used. In a sense, they are assumed to be in the Blue part of the combat sector. In this case, the shelters given by BSARF(IB,IFPBS) are assumed to be useless that day. If these shelters are behind the combat sector but are within DSB + DFRB of FPS (i.e., if FPS + DSB < FPBS(IFPBS) $\leq$ FPS + DSB + DFRB), then these shelters are assumed to be available to the aircraft based on the forward-region airbase--i.e.,

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$$BSARF(IB) = \Sigma \; BSARF(IB,IFPBS) \; ,$$

when the sum is over all IFPBS such that

$$FPS + DSB < FPBS(IFPBS) \leq FPS + DSB + DFRB \; .$$

The same structure holds for determining the shelters available to the rear-region and COMMZ airbases--i.e.,

$$BSARR(IB) = \Sigma \; BSARF(IB,IFPBS) \; ,$$

where the sum is over all IFPBS such that

$$FPS + DSB + DFRB < FPBS(IFPBS) \leq FPS + DSB + DFRB + DRRB \; ,$$

and

$$BSAZ = \sum \left(\sum_{IB=1}^{NIB} BSARF(IB,IFPBS) \right)$$

where the outer sum is over all IFPBS such that

$$FPS + DSB + DRFB + DRRB < FPBS(IFPBS) \leq FPS + DSB$$
$$+ DRFB + DRRB + DZB.$$

If the shelters are beyond this last distance--i.e., if

$$FBPS(IFPBS) > FPS + DSB + DFRB + DRRB + DZB \; ,$$

then the shelters are assumed to be too far away from the FEBA to be available even to the COMMZ airbase.

B.   SUPPLIES

Each Blue type-KBA aircraft is assumed to consume BSCA(KBA) tons of supply per day. Let TBSCA be the total tons of supplies demanded by Blue aircraft--i.e., TBSCA =

$$\sum_{KBA} \left(\sum_{IB} (BAFR(KBA,IB) + BARR(KBA,IB)) + BAZ(KBA) \right) * BSCA(KBA) \; .$$

If there are enough supplies in the COMMZ to satisfy all the aircraft, then all supplies for aircraft are drawn from that pool. So if TBSCA $\leq$ BGSZ, then BGSZ is replaced by BGSZ - TBSCA and aircraft will not be limited by supply shortage. If TBSCA > BGSZ, then BGSZ is set equal to 0.0 and the remaining demand, TBSCA - BGSZ, is filled by the region supply pools. If

$$TBSCA - BGSZ \leq \sum_{IB} BGSR(IB) ,$$

then BGSR(IB) is replaced by

$$(TBSCA - BGSZ) * \left(BGSR(IB) / \sum_{IB} BGSR(IB) \right) ,$$

and aircraft will not be limited by supply shortage. If

$$TBSCA > BGSZ + \sum_{IB} BGSR(IB) ,$$

then BGSZ and BGSR(IB) for all IB are set equal to 0.0, and the sortie role for each type of aircraft is multiplied by a factor of

$$\left(BGSZ + \sum_{IB} BGSR(IB) \right) / TBSCA ,$$

to account for the reduced number of sorties flown due to the shortage of supplies. (Actually, the sortie rates are multiplied by the maximum of this factor and EPSLON, so that at the end of the air-combat model they can be divided by this maximum to restore them to their input values.)

Similar computations are made for Red, and all these computations are made in part 1 of the air-combat model (AC1).

C. ASSIGNMENT OF AIRCRAFT BY LOCATION

Let

PBAM(KBA) = the percent of Blue type-KBA aircraft that are assigned to type-M missions,

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where

  M = 1 denotes close air support (CAS);

  M = 2 denotes close-air-support escort (CASE);

  M = 3 denotes battlefield defense (BD);

  M = 4 denotes airbase attack (ABA);

  M = 5 denotes airbase-attack escort (ABAE);

  M = 6 denotes airbase defense (ABD); and

  M = 7 denotes interdiction of division in reserve (IDR).

The PBAM(KBA) are inputs to IDAGAM I.[1] However, these variables alone are not sufficient to determine Blue aircraft assignments, because they do not give the location that the aircraft come from (i.e., the airbase on which they are stationed) or the location they are attacking (i.e., which sector for CAS aircraft, which Red airbase for ABA aircraft, etc.). IDAGAM I computes aircraft assignments based on the PBAM(KBA) and on the location of the "home" airbase and the location of the target. The purpose of this section is to out-line how these computations are made. For the purpose of this section, we will call the PBAM(KBA) "input assignments" and the assignments considering locations "locational assignments."

The computation of locational assignments can be described in terms of five steps as follows:

(1) Compute weighted number of aircraft on each Red airbase.

(2) Compute Blue aircraft assignment for planes based on the COMMZ airbase.

(3) Compute Blue aircraft assignment for planes based on the rear-region airbases (except for CAS missions).

(4) Compute Blue aircraft assignment for planes based on the forward-region airbases (except for CAS missions).

(5) Compute Blue aircraft assignment to sectors for CAS missions.

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[1]Symmetric definitions and computations are made for Red. Rather than continually repeating this statement, we will give in this section the definitions and computations only for Blue attacking Red.

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Each of these steps is now discussed in detail:

Step 1. As discussed below, one fact considered in determining which Red airbases the Blue aircraft on ABA missions will attack is the number of Red aircraft on each Red airbase. The idea is that ABA aircraft should not be sent to attack an airbase with few aircraft stationed on it while another airbase has many aircraft on it. However, it is also important to consider the sheltering of aircraft. If two airbases have an equal number of aircraft based on them (but all the aircraft on one airbase are sheltered while none of the aircraft on the other airbases are sheltered), then the latter airbase should, in general, be more desirable to attack. The way that IDAGAM I considers this structure is to weight the number of sheltered aircraft by an input weighting factor and then to add this weighted number of (sheltered) aircraft to the actual number of unsheltered aircraft, to determine the total weighted number of aircraft on the airbase. This total weighted number is then used to compute assignments. The particular computations made in this step are as follows:

$$WRAZ = \left(MIN \left\{ RSAZ, \sum_{KRA} RAZ(KRA) \right\} * WFCRSN \right)$$

$$+ \left(\sum_{KRA} RAZ(KRA) - MIN \left\{ RSAZ, \sum_{KRA} RAZ(KRA) \right\} \right) ,$$

$$WRARR(IR) = \left(MIN \left\{ RSARR(IR), \sum_{KRA} RARR(KRA,IR) \right\} * WFCRSN \right)$$

$$+ \left(\sum_{KRA} RARR(KRA,IB) \right.$$

$$\left. - MIN \left\{ RSARR(IR), \sum_{KRA} RARR(KRA,IR) \right\} \right) ,$$

$$WRAFR(IR) = \left(MIN\ \{RSAFR(IR),\ \sum_{KRA}\ RAFR(KRA,IR)\}\ *\ WFCRSN\right)$$

$$+\ (\sum_{KRA}\ RAFR(KRA,IR)$$

$$-\ MIN\ \{RSAFR(IR),\ \sum_{KRA}\ RAFR(KRA,IR)\})\ ,$$

Step 2. The computations described in this step and the next two steps are made once for each type of aircraft.

If $IRBAZ(KBA) = 5$, then type-KBA aircraft based in the COMMZ are not limited by range considerations, and so aircraft on ABA missions can attack any airbase. IDAGAM I assumes that they attack airbases in proportion to the weighted number of Red aircraft on these airbases.

Let

$$WRA = WRAZ + \sum_{IB}\ \left(WRARR(IB) + WRAFR(IB)\right)\ .$$

If $WRA \leq RAFBCA$, then there are not enough (weighted) Red aircraft on all the Red airbases to make it worthwhile for Blue to send any aircraft on ABA missions. The model treats this case in the same way as the case where $IRBAZ(KBA) = 2$.

If $WRA > RAFBCA$, then

$$PBAZ4Z(KBA) = PBA4(KBA) * (WRAZ/WRA)\ ,$$
$$PBAZ5Z(KBA) = PBA5(KBA) * (WRAZ/WRA)\ ,$$

and

$$PBAZ4R(KBA,IR) = PBA4(KBA) * (WRARR(IR)/WRA)\ ,$$
$$PBAZ5R(KBA,IR) = PBA5(KBA) * (WRARR(IR)/WRA)\ ,$$
$$PBAZ4F(KBA,IR) = PBA4(KBA) * (WRAFR(IR)/WRA)\ ,$$
$$PBAZ5F(KBA,IR) = PBA5(KBA) * (WRAFR(IR)/WRA)\ ,$$

for all IR.

If IRBAZ(KBA) = 4, the same calculations are made--except that

$$WRA = \sum_{IR} \left(WRARR(IR) + WRAFR(IR) \right)$$

and

$$PBAZ4Z(KBA) = PBAZ5Z(KBA) = 0.0 \ ,$$

since then type-KBA aircraft cannot reach the Red COMMZ air force from the Blue COMMZ.

If IRBAZ(KBA) = 3, the same calculations are made--except that

$$WRA = \sum_{IR} WRAFR(IB)$$

and

$$PBAZ4Z(KBA) = PBAZ5Z(KBA) = 0.0 \ ,$$

and

$$PBAZ4R(KBA,IR) = PBAZ5R(KBA,IR) = 0.0$$

for all IR.

If IRBAZ(KBA) $\geq$ 3, then PBAZ7F(KBA,IR) = PBA7(KBA) if IR is the region with the largest number of Red divisions in reserve; otherwise, PBAZ7F(KBA,IR) = 0.0. (If there are no Red divisions in reserve in any region, then this case is treated as if IRBAZ(KBA) = 2; and if two or more regions have the same number of Red divisions in reserve, then PBA7(KBA) is split evenly between them.)

If IRBAZ(KBA) = 2, then type-KBA aircraft cannot perform ABA, ABAE, or IDR missions from the COMMZ because they cannot reach any Red airbases, nor can they reach the Red divisions in reserve. In this case, PBA4(KBA) and PBA7(KBA) are added to PBA1(KBA); and PBA5(KBA) is added to PBA2(KBA)--i.e., aircraft that would have been assigned to ABA and IDR missions are

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assigned instead to CAS missions, and aircraft that would have been assigned to ABAE missions are assigned instead to CASE missions.

If IRBAZ(KBA) $\geq$ 2, then the aircraft assigned to fly CAS and CASE missions can perform them. Let APA1 be the additional percent of type-KBA aircraft based on the COMMZ airbase that fly CAS missions (due to the reasons described above), and let APA2 be the additional percent that fly CASE missions. If Blue is on defense in the theater, let JMF be the sector with the maximum Red penetration. If Blue is on attack, let JMF be the sector with the maximum Blue penetration (or equivalently, minimum Red penetration)--unless MCSMAB = 2, in which case JMF is the sector with the minimum Blue penetration. Then

$$PBAZ1(KBA,J) = \begin{cases} PBA1(KBA) + APA1 \text{ , if } J = JMF; \\ 0.0 \text{ ,} \qquad\qquad \text{otherwise;} \end{cases}$$

and

$$PBAZ2(KBA,IR) = \begin{cases} PBA2(KBA) + APA2 \text{ , if } JMF \; \epsilon \; IR; \\ 0.0 \text{ ,} \qquad\qquad \text{otherwise.}^1 \end{cases}$$

In addition, if IRBAZ(KBA) $\geq$ 2, then Blue type-KBA aircraft assigned to fly BD missions can perform them. These aircraft are assigned to defend in Blue region containing the sector in which the CAS aircraft are attacking. Thus,

$$PBAZ3(KBA,IB) = \begin{cases} PBA3(KBA) \text{ , if } JMF \; \epsilon \; IB; \\ 0.0 \text{ ,} \qquad \text{otherwise.} \end{cases}$$

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[1]Red aircraft assigned to BD missions are assumed to be assigned to a particular Red region and are able to defend any sector in that region. Accordingly, Blue escorts are assumed to be able to engage any Red aircraft in the Red region containing the sector in which the Blue attackers are attacking, and so the Blue escorts are assigned by location to Red regions (and vice versa, for Red attacking Blue).

If IRBAZ(KBA) $\geq$ 2, then all type-KBA aircraft not assigned to ABD missions have been assigned by the methods described above. But if IRBAZ(KBA) = 1, then type-KBA aircraft cannot fly any missions other than ABD, as they cannot even reach the FEBA from the COMMZ airbase. Accordingly,

$$PBA6Z(KBA) = \begin{cases} PBA6(KBA) , & \text{if } IRBAZ(KBA) \geq 2; \\ 1.0 , & \text{if } IRBAZ(KBA) = 1 . \end{cases}$$

Step 3. The locational assignments for aircraft based on region airbases is considered in roughly the same way as for aircraft based on the COMMZ airbase--with three major exceptions. First, aircraft based in Blue region 1, for example, might not be able to attack airbases in Red region 3 (and vice versa). This is handled using the variable FBARRR(IB,IR).

Second, aircraft based in regions on ABA missions will attempt to attack enemy aircraft based in regions before attacking enemy aircraft based in the COMMZ.

Third, IDAGAM I makes a special consideration for the case where, due to range considerations, aircraft based on the rear-region airbases are sent on CAS and CASE missions instead of ABA and ABAE missions. The best way to explain this consideration is through an example. Suppose that a user of IDAGAM I wants 40 percent of the Blue type-KBA aircraft to fly ABA missions and 60 percent to fly CAS missions. Suppose, further, that there is an equal number of Blue type-KBA aircraft on each Blue regional airbase; that no type-KBA aircraft are based in the COMMZ; and that type-KBA aircraft on the Blue rear-region airbases cannot reach any Red airbase, but that they can reach the FEBA. Then IDAGAM I will send all the type-KBA aircraft from rear-region airbases on CAS missions, but it will note that 40 percent of them were to have gone on ABA missions. Then, in allocating type-KBA aircraft based on the forward-region airbases, IDAGAM I

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will consider this 40 percent and send 80 percent of the type-KBA aircraft based on the forward-region airbases on ABA missions and 20 percent on CAS missions. Therefore, overall, Blue will send 40 percent of its type-KBA aircraft on ABA missions and 60 percent on CAS missions--which matches the input. If the inputs were reversed (60 percent to ABA missions, 40 percent to CAS), then it would not be possible for the actual allocation to match the inputs, since 50 percent of the type-KBA aircraft are too far from the Red airbases to fly ABA missions. In this case, IDAGAM I will send all the rear-region type-KBA aircraft on CAS missions and all the forward-region type-KBA aircraft on ABA missions. This results in a 50-50 allocation, which is as close as possible to the input allocation.

The computations described in this step and in the next step are made once for each Blue region (as noted above, these computations are also made once for each type of aircraft).

If $IRBAR(KBA) \geq 4$, then Blue type-KBA aircraft can attack both forward- and rear-region Red air forces. In this case,

$$WRA = \sum_{IR} \Big(\big(WRAFR(IR) + WRARR(IR)\big) * FBARRR(IB,IR) \Big) .$$

If $WRA \leq RAFBCA$, then there are not enough weighted Red aircraft in the appropriate Red regional airbases to make it worthwhile for Blue to attack these airbases. If this is the case, and if $IRBAR(KBA) = 4$, then these aircraft cannot attack the COMMZ airbase; and they are treated in the same way as the case where $IRBAR(KBA) = 2$. If $IRBAR(KBA) = 5$ and $WRAZ \leq RAFBCA$, they are also treated in the same way as the case where $IRBAR(KBA) = 2$. If $IRBAR(KBA) = 5$ and $WRAZ > RAFBCA$, then

$$PBAR4Z(KBA,IB) = PBA4(KBA) ,$$
$$PBAR5Z(KBA,IB) = PBA5(KBA) ,$$

and

$$\text{PBAR4R(KBA,IB,IR)} = \text{PBAR5R(KBA,IB,IR)} = 0.0 \ ,$$

$$\text{PBAR4F(KBA,IB,IR)} = \text{PBAR5F(KBA,IB,IR)} = 0.0 \ ,$$

for all IR.

If $\text{IRBAR(KBA)} \geq 4$ and, with WRA as defined above, WRA > RAFBCA, then

$$\text{PBAR4R(KBA,IB,IR)} = \text{PBA4(KBA)} * \frac{\text{WRARR(IR)} * \text{FBARRR(IB,IR)}}{\text{WRA}} \ ,$$

$$\text{PBAR5R(KBA,IB,IR)} = \text{PBA5(KBA)} * \frac{\text{WRARR(IR)} * \text{FBARRR(IB,IR)}}{\text{WRA}} \ ,$$

$$\text{PBAR4F(KBA,IB,IR)} = \text{PBA4(KBA)} * \frac{\text{WRAFR(IR)} * \text{FBARRR(IB,IR)}}{\text{WRA}} \ ,$$

$$\text{PBAR5F(KBA,IB,IR)} = \text{PBA5(KBA)} * \frac{\text{WRAFR(IR)} * \text{FBARRR(IB,IR)}}{\text{WRA}} \ ,$$

for all IR; and

$$\text{PBAR4Z(KBA,IB)} = \text{PBAR5Z(KBA,IB)} = 0.0 \ .$$

The rationale for the term $\dfrac{\text{WRARR(IR)} * \text{FBARRR(IB,IR)}}{\text{WRA}}$ is the same as the rationale for the allocation term in the ground-combat attrition process described in Volume 1. In the notation of Volume 1, an allocation of fire is given by

$$\frac{A_{ij}^{*bgd} R_j / R_j^{*}}{\sum\limits_{j\prime} A_{ij\prime}^{*bgd} R_{j\prime} / R_{j\prime}^{*}} \ ,$$

where R_j is the actual number of Red type-j weapons in combat, R_j^{*} is the number of Red weapons in a standard force, and A_{ij}^{*bgd} gives the allocation of Blue fire against a standard Red force. Here, instead of a "standard force," we use the idea of an equal number of weighted Red aircraft on each Red airbase as being "standard." And FBARRR(IB,IR) is the allocation of Blue aircraft that would occur if there were an equal number of Red aircraft on each Red airbase. Substituting FBARRR(IB,IR) for A_{ij}^{*bgd}, "x" for R_j^{*}, and WRARR(IR) and WRAFR(IR) for R_j in

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the allocation-of-fire term (above) gives

$$\frac{\Bigl(FBARRR(IB,IR) \ast WRARR(IR)\Bigr) \big/ x}{\displaystyle\sum_{IR'}\Biggl(FBARRR(IB,IR') \ast \Bigl(WRARR(IR') + WRAFR(IR')\Bigr)\Biggr)\big/ x} \; ,$$

which equals

$$\frac{WRARRR(FR) \ast FBARRR(IB,IR)}{WRA} \; ,$$

which is the allocation used here. This allocation has all the
desired properties that correspond to the ground-fire alloca-
tion--i.e., if there are no aircraft on a particular Red airbase
(WRARR(IR) = 0.0), then no Blue aircraft attack that airbase;
if a particular Red airbase has all the Red aircraft, then all
the Blue aircraft attack that airbase and no other; and if
there is an equal weighted number of Red aircraft on all Red
airbases (WRARR(IR) = WRAFR(IR') for all IR and IR'), then the
allocation is given by the input allocation FBARRR(IB,IR).

If IRBAR(KBA) = 3, then the same calculations are made--
except that

$$WRA = \sum_{IR} WRAFR(IR) \ast FBARRR(IB,IR)$$

and

$$PBAR4R(KBA,IB,IR) = PBAR5R(KBA,IB,IR) = 0.0 \; .$$

If IRBAR(KBA) $\geq$ 3, then PBAR7F(KBA,IB,IR) =

$$PBA7(KBA) \ast \frac{\displaystyle\sum_{KRD} NRDR(KRD,IR) \ast PNRD(KRD') \ast FBARRR(IB,IR)}{\displaystyle\sum_{IR'} \sum_{KRD'} NRDR(KRD',IR') \ast PNRD(KRD') \ast FBARRR(IB,IR')} \; ,$$

using the same allocation logic described above.

If IRBAR(KBA) = 2, then type-KBA aircraft cannot perform
ABA, ABAE, or IDR missions from the rear-region airbase. In this
case, aircraft that would have been assigned to ABA and IDR

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missions are assigned instead to CAS missions $(APA1 = PBA4(KBA) + PBA7(KBA))$; and aircraft that would have been assigned to ABAE missions are assigned instead to CASE missions $(APA2 = PBA2(KBA))$. As described above, in this case, type-KBA aircraft will be flying CAS (and CASE) missions instead of ABA (and ABAE) missions from the rear-region airbase. Accordingly, to compensate for this adjustment, some type-KBA aircraft should fly ABA (and ABAE) missions instead of CAS (and CASE) missions from the forward-region airbase--to accomplish which the variable PAU45 is set equal to BARR(KBA,IB)/BAFR(KBA,IB) for this case (otherwise, it is 0.0). The use of PAU45 will be described below.

If $IRBAR(KBA) \geq 2$, then the aircraft assigned to fly CAS, CASE, and BD missions can perform them. The sectors in which the CAS aircraft will attack will be determined in Step 5 (below). Inputs for Step 5 from this step are the percent of type-KBA aircraft assigned to CAS and CASE missions. These percentages are

$$PAR1T(KBA,IB) = PBA1(KBA) + APA1 \; ,$$
$$PAR2T(KBA,IB) = PBA2(KBA) + APA2 \; .$$

For aircraft on BD missions, if $IRBAR(KBA) \geq 2$, then

$$PBAR3(KBA,IB) = PBA3(KBA) \; .$$

Just as for aircraft based on the COMMZ airbase, if $IRBAR(KBA) = 1$, then type-KBA aircraft based on the rear-region airbase can fly no mission other than ABD; and so

$$PBAR6(KBA,IB) = \begin{cases} PBA6(KBA) \; , & \text{if } IRBAR(KBA) \geq 2; \\ 1.0 \; , & \text{if } IRBAR(KBA) = 1 \; . \end{cases}$$

Step 4. As stated above, the computations in this step are made once for each type of aircraft and for each region. With two exceptions, these computations are identical to those made for the rear-region airbase; and so, except for the exceptions, they will not be described here.

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The first exception is that the model does not test to see if IRBAF(KBA) = 1. If IRBAF(KBA) ≤ 2, the model assumes that it equals 2. This assumption is made because if a type-KBA aircraft can fly only ABD missions, then PBA6(KBA) should be set equal to 1.0. And if a type-KBA aircraft can fly any other mission, then it must be able to do so at least from the forward-region airbases. Therefore, logical inputs require that either PBA6(KBA) = 1.0 or IRBAF(KBA) ≥ 2 (or both), and thus there is no need to test for IRBAF(KBA) = 1.

The second exception is the computation of the percent of type-KBA aircraft sent on ABA, ABAE, CAS, and CASE missions. If PBA4(KBA) of the total type-KBA aircraft in region IB (BARR(KBA) + BAFR(KBA)) are to be sent on ABA missions (and if none were sent from the rear-region airbase), and if PAA4 is the additional percent of type-KBA aircraft sent on ABA missions from the forward-region airbase, then PAA4 must satisfy

[PAA4 + PBA4(KBA)] * BAFR(KBA) = PBA4(KBA) * [BARR(KBA) + BAFR(KBA)]

or

$$PAA4 = PBA4(KBA) * \frac{BARR(KBA)}{BAFR(KBA)} = PBA4(KBA) * PAU45 \ .$$

But, since this additional percent is to be taken from the percent of aircraft assigned to CAS missions, it cannot be greater than PBA1(KBA). Therefore,

$$PAA4 = MIN \{PBA4(KBA) * PAU45, PBA1(KBA)\} \ .$$

Likewise,

$$PAA5 = MAX \{PBA5(KBA) * PAU45, PBA2(KBA)\} \ .$$

The formulas used to compute locational assignments for ABA, ABAE, CAS, and CASE missions for the forward-region airbase are the same as for the rear-region airbase, except that PBA4(KBA) + PAA4, PBA5(KBA) + PAA5, PBA1(KBA) - PAA4, and PBA2(KBA) - PAA5 appear in the formulas for forward-region

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assignments in place of PBA4(KBA), PBA5(KBA), PBA1(KBA), and PBA2(KBA), respectively.

Step 5. From Steps 3 and 4, we have the percent of Blue aircraft to be assigned to CAS and CASE missions from each Blue regional airbase.

This step takes these percent assignments to CAS missions and determines the sectors in which the aircraft on those missions attack. This step also determines the Red regions that contain the sectors in which the aircraft on CASE missions are performing.

With one exception (noted below), CAS aircraft always attack in sectors that are contained in the region in which those aircraft are based. Three considerations are made in determining in which sectors in that region these aircraft should attack. First, if Blue is the theater attacker and if the ground force ratio in a sector is less than an input value (or if Blue is the theater defender and the ground force ratio is greater than an input value), then CAS missions are sent to that sector until the resulting force ratio equals the appropriate input value (or until Blue has assigned all his CAS aircraft). Second, if Blue is the theater attacker and if the sector of main attack in the region is constrained by front-to-flank ratio, then any CAS aircraft not assigned by the first consideration are assigned to support in a flanking sector. Finally, the CAS aircraft not assigned by the first or second considerations are assigned to support in the sector of maximum penetration (if Blue is on defense) or to support in the sector of main attack (if Blue is on attack and the sector of main attack is not constrained by front-to-flank ratio).

Suppose that Blue is on attack in the theater. Then, to handle the first consideration described above, let

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$$\text{VNS}(J) = \text{the value needed in sector } J$$
$$= \text{MAX} \left\{ 0, \ (\text{ABRFBA} * \text{RDWVS}(J)) - \text{BAWVS}(J) \right\} ,$$
$$\text{VNR} = \text{the value needed in all sectors in region IB}$$
$$= \sum_{J \epsilon IB} \text{VNS}(J) ,$$
$$\text{AVA} = \text{the total air value available to Blue in region IB}$$
$$= \sum_{KBA} \bigg(\ (\text{PAR1T}(\text{KBA},\text{IB}) * \text{BARR}(\text{KBA},\text{IB}))$$
$$+ \ (\text{PAF1T}(\text{KBA},\text{IB}) * \text{BAFR}(\text{KBA},\text{IB})) * \text{VBAASF}(\text{KBA}) \bigg) ,$$

PCASS(J) = the percent of Blue aircraft on CAS missions that are sent to sector J (this is to be calculated).

If VNR $\leq$ 0, then no CAS missions need to be assigned by this consideration; and so the second consideration is tested. If VNR > 0, then PCASS(J) = $(\text{VNS}(J)/\text{VNR})$ * MIN {1, VNR/AVA} for all J ϵ IB. If VNR/AVA $\geq$ 1, then all the CAS aircraft have been assigned and the second and third considerations can be skipped. If not, then front-to-flank ratio is considered.

The variable ISCFFR(J) states whether sector J is constrained by front-to-flank ratio. If no sectors in the region are so constrained, the third consideration is addressed. If a sector in the region is so constrained, then all the remaining CAS aircraft are sent to the flanking sector with the worst (most constraining to Blue) FEBA position. If this sector is not in the same region, then the variable IBAFCR is used to determine if the Blue air forces can cross the region boundary.

If not all CAS aircraft have been assigned by the first consideration and if no sector in the region is constrained by front-to-flank ratio, then the remaining CAS aircraft are sent to the sector of main attack. Let JRA be the sector of main attack in the region (for the attacker). Then

$$\text{PCASS}(\text{JRA}) = 1 - \sum_{\substack{J \epsilon IR \\ J \neq RA}} \text{PCASS}(J) .$$

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With PCASS(J), we can calculate

$$PBAR1(KBA,IB,J) = PCASS(J) * PAR1T(KBA,IB)$$

and

$$PBAF1(KBA,IB,J) = PCASS(J) * PAF1T(KBA,IB) \ .$$

If Blue is on defense, then the front-to-flank ratio constraints are not considered; and the rest of the calculations are made with "Blue attack" variables replaced by "Blue defense" variables (and vice versa for Red) and with JRA being the sector of maximum penetration.

In considering CASE aircraft, the basic idea is that these aircraft should be assigned in a manner consistent with CAS assignments. These assignments are made by setting

$$PBAR2(KBA,IB,IR) = PAR2T(KBA,IB) * \sum_{J \epsilon IR} PCASS(J)$$

and

$$PBAF2(KBA,IB,IR) = PAF2T(KBA,IB) * \sum_{J \epsilon IR} PCASS(J) \ .$$

Similar computations are made for Red, and all these computations are made in part 1 of the air-combat model (AC1).

D. AIRCRAFT ASSIGNMENT TOTALS

In Section C, percentage assignments for aircraft were calculated. In this section, these percentages are multiplied by the number of aircraft on each airbase and the appropriate sortie rates, to obtain the actual assignments; and these actual assignments are summed over the home airbases, to obtain the actual number of aircraft (by type) assigned to each mission by location of that mission.

The equations for Blue are as follows:

$$BACA(KBA,J) = \left(\sum_{IB} \left(\left(BAFR(KBA,IB) * PBAF1(KBA,IB,J) \right) \right.\right.$$
$$\left. + \left(BARR(KBA,IB) * PBAR1(KBA,IB,J) \right) \right)$$
$$\left. + \left(BAZ(KBA) * PBAZ1(KBA,J) \right) \right) * SRB1(KBA) \ .$$

$$BACE(KBA,IR) = \left(\sum_{IB} \left(\left(BAFR(KBA,IB) * PBAF2(KBA,IB,IR) \right) \right.\right.$$
$$\left. + \left(BARR(KBA,IB) * PBAR2(KBA,IB,IR) \right) \right)$$
$$\left. + \left(BAZ(KBA) * PBAZ2(KBA,IR) \right) \right) * SRB2(KBA) \ .$$

$$BACD(KBA,IB) = \left(\left(BAFR(KBA,IB) * PBAF3(KBA,IB) \right) \right.$$
$$+ \left(BARR(KBA,IB) * PBAR3(KBA,IB) \right)$$
$$\left. + \left(BAZ(KBA) * PBAZ3(KBA,IB) \right) \right) * SRB3(KBA) \ .$$

$$BAFA(KBA,IR) = \left(\sum_{IB} \left(\left(BAFR(KBA,IB) * PBAF4F(KBA,IB,IR) \right) \right.\right.$$
$$\left. + \left(BARR(KBA,IB) * PBAR4F(KBA,IB,IR) \right) \right)$$
$$\left. + \left(BAZ(KBA) * PBAZ4F(KBA,IR) \right) \right) * SRB4(KBA) \ .$$

$$BAFE(KBA,IR) = \left(\sum_{IB} \left(\left(BAFR(KBA,IB) * PBAF5F(KBA,IB,IR) \right) \right.\right.$$
$$\left. + \left(BARR(KBA,IB) * PBAR5F(KBA,IB,IR) \right) \right)$$
$$\left. + \left(BAZ(KBA) * PBAZ5F(KBA,IR) \right) \right) * SRB5(KBA) \ .$$

$$BAFD(KBA,IB) = \left(BAFR(KBA,IB) * PBAF6(KBA,IB) \right) * SRB6(KBA) \ .$$

BARA(KBA,IR), BARE(KBA,IR), and BARD(KBA,IB) are calculated in
an analogous manner; and

$$BAZA(KBA) = \left(\sum_{IB} \left(\left(BAFR(KBA,IB) * PBAF4Z(KBA,IB) \right) \right.\right.$$
$$\left. + \left(BARR(KBA,IB) * PBAR4Z(KBA,IB) \right) \right)$$
$$\left. + \left(BAZ(KBA) * PBAZ4Z(KBA) \right) \right) * SRB4(KBA) \ .$$

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$$BAZE(KBA) = \left(\sum_{IB} \left(\big(BAFR(KBA,IB) * PBAF5Z(KBA,IB)\big) \right. \right.$$
$$\left. + \big(BARR(KBA,IB) * PBAR5Z(KBA,IB)\big) \right)$$
$$\left. + \big(BAZ(KBA) * PBAZ5Z(KBA)\big) \right) * SRB5(KBA) \ .$$

$$BAZD(KBA) = \big(BAZ(KBA) * PBAZ6(KBA)\big) * SRB6(KBA) \ .$$

$$BAIDR(KBA,IR) = \left(\sum_{IB} \left(\big(BAFR(KBA,IB) * PBAF7F(KBA,IB,IR)\big) \right. \right.$$
$$\left. + \big(BARR(KBA,IB) * PBAR7F(KBA,IB,IR)\big) \right)$$
$$\left. + \big(BAZ(KBA) * PBAZ7F(KBA,IR)\big) \right) * SRB7(KBA) \ .$$

Similar computations are made for Red, and all these computations are made in part 2 of the air-combat model (AC2).

E.   ASSIGNMENT OF AIRCRAFT TO SECONDARY MISSIONS

1.   SAM Suppression and AAA Suppression in Combat Sectors

There are four basic principles behind the computation of how many aircraft are sent on SAM- and AAA-suppression missions. The first principle is that the number of aircraft sent on these missions will be taken out of the aircraft sent on CAS missions. So if SUPM(KBA) is the number of type-KBA aircraft on suppression missions in sector J, then BACA(KBA,J) is replaced by BACA(KBA,J) minus SUPM(KBA); and the SUPM(KBA) aircraft are divided between SAM- and AAA-suppression missions.

The second principle is that SUPM(KBA) will depend on the number of targets (SAMs and AAA) and on the number of CAS sorties flown $\left(\sum_{KBA} BACA(KBA) \right)$. The idea here is that if few CAS sorties are being flown, then they all should attack primary targets rather than fly suppression missions. However, above an input threshold (BMCASS), an input percent of the CAS missions flown by type-KBA aircraft (PBACS(KBA)) are diverted from CAS to SAM- or AAA-suppression missions, provided that there are

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enough SAMs and AAA in the sector as targets. Let TSUP be the
weighted number of SAMs and AAA in the sector (the weighting
procedure will be discussed below); then no more than (BMSPSC *
TSUP) aircraft are sent on suppression missions. (BMSPSC is,
in a sense, the saturation rate for attacking SAMs.) If there
were only one type of aircraft (NKBA = 1), then a picture would
look like the following:
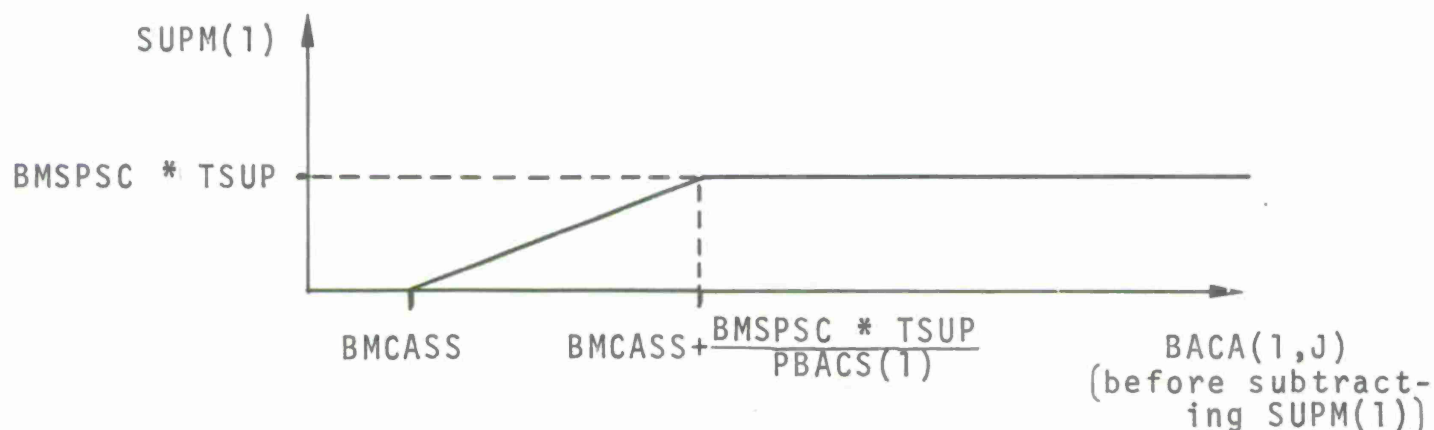
The same concept applies for NKBA > 1, and the equations will
be given below.

The third principle considers how the number of aircraft
on suppression missions (TSUP) are allocated between SAM- and
AAA-suppression missions. The principle here is to use the
ground-weapon allocation structure in the same way that the
computation of the weighted number of aircraft on an airbase
uses this allocation structure--i.e., the "standard" target
force is thought of as consisting of an equal number of SAMs
and AAA, and the input variable FBASAG gives the fraction of
TSUP(KBA) that attack AAA (the remaining (1-FBASAG) attack
SAMs) if there were an equal number of AAA and SAMs. With
RSS(J) denoting the actual number of Red SAMs in sector J and
RGS(J) denoting the actual number of Red AAA in sector J, then
the actual fraction of TSUP(KBA) that attack AAA is

$$\frac{FBASAG * RGS(J)}{\big((1 - FBASAG) * RSS(J)\big) + \big(FBASAG * RGS(J)\big)} \quad ,$$

and 1 minus this fraction attack SAMs. Again, we note that this method is precisely the same as that used to allocate shooters to targets as described in Volume 1 for ground weapons; only here this allocation is for the special case where there are only two types of targets (SAMs and AAA), and the "standard" target force is assumed to consist of an equal number of targets of each type.

Just as was done above to compute the weighted number of aircraft on an airbase, the weighted number of targets (SAMs and AAA) is computed by adding the number of SAMs to a weighting factor times the number of AAA, where the weighting factor is given by FBASAG/(1 - FBASAG).

The fourth principle is that the missiles fired by the SAMs (i.e., by the SAM launchers) are scarce resources and should be accounted for. The total number of such missiles in the theater for Red is given by TRSAM. If TRSAM < 1, then the Red SAMs are assumed to be completely ineffective (since they have no missiles to fire) and Blue is assumed to send all its aircraft on suppression missions against AAA. This assumption is made in the program by defining TBASAG as

$$TBASAG = \begin{cases} FBASAG \text{ , if } TRSAM \geq 1; \\ 1.0 \text{ , } \quad \text{if } TRSAM < 1; \end{cases}$$

and then using TBASAG in place of FBASAG in the allocation computations.

The formulas used in this section are as follows:

$$SUM = \sum_{KBA} BACA(KBA,J) \text{ .}$$

$$\text{SUPM(KBA)} = \text{MAX} \left\{ 0.0, \left(\text{BACA(KBA,J)} - \left(\frac{\text{BACA(KBA,J)}}{\text{SUM}} * \text{BMCASS} \right) \right) * \text{PBACS(KBA)} \right\}$$

$$\text{SUPM(KBA)} \leftarrow \text{MIN} \left\{ \text{SUPM(KBA)}, \text{BMSPSC} * \text{TSUP} * \frac{\text{SUPM(KBA)}}{\sum\limits_{\text{KBA}'} \text{SUPM(KBA}')} \right\},$$

$$\text{where TSUP} = \begin{cases} \text{RSS(J)} + \dfrac{\text{TBASAG}}{1 - \text{TBASAG}} * \text{RGS(J)} & \text{, if TBASAG} < 1 \text{ ;} \\ \\ \text{RGS(J)} \text{ ,} & \text{if TBASAG} = 1 \text{ .} \end{cases}$$

$$\text{BACA(KBA,J)} \leftarrow \text{BACA(KBA,J)} - \text{SUPM(KBA)} \text{ .}$$

$$\text{BACG(KBA,J)} = \begin{cases} 0, & \text{if RGS(J)} = 0; \\ \text{SUPM(KBA)} \text{ ,} & \text{if RGS(J)} > 0, \text{ RSS(J)} = 0; \\ \text{SUPM(KBA)} * \\ \quad \dfrac{\text{TBASAG} * \text{RGS(J)}}{((1 - \text{TBASAG}) * \text{RSS(J)}) + (\text{TBASAG} * \text{RGS(J)})} \text{ ,} \\ \hfill \text{otherwise.} \end{cases}$$

$$\text{BACS(KBA,J)} = \text{SUPM(KBA)} - \text{BACG(KBA,J)} \text{ .}$$

2. SAM Suppression and AAA Suppression Around Airbases

The concepts and calculations for determining the number of aircraft to suppress SAMs and AAA defending airbases are the same as described above for suppression missions in combat sectors. The only differences are the variables used. Instead of the parameters BMCASS, PBACS, and BMSPSC, the model uses here the inputs BMABAS, PBAAS, and BMSPSA. Instead of calculating BACG(KBA,J) and BACS(KBA,J), the model calculates BAFG(KBA,IR) and BAFS(KBA,IR); BARG(KBA,IR) and BARS(KBA,IR); and BAZG(KBA) and BAZS(KBA) (for the forward-region airbases; rear-region airbases; and COMMZ airbases, respectively). And instead of using BACA(KBA,J), RSS(J), and RGS(J), the model uses BAFA(KBA,IR), RSFR(IR), and RAGFR(IR); BARA(KBA,IR), RSAMRR(IR), and RAGRR(IR); and BAZA(KBA), RSAMZ, and RAGZ (for the forward-region airbases; rear-region airbases; and COMMZ airbases, respectively). RSFR(IR

is defined by

$$RSFR(IR) = RSAMFR(IR) + \sum_{KRD} RWDR(NKRW,KRD,IR) \; ,$$

because it is assumed that since the Red SAMs in divisions in the region can defend airbases in the forward part of the region as well as defending their divisions, they can be targets for SAM suppression as well.

Computations similar to those already described are made for Red; and all these computations are made in part 2 of the air-combat model (AC2).

3.   Supply Interdiction

Aircraft that attack supplies in sectors and supplies en route from regions to sectors come from the remaining CAS aircraft after the suppressors have been subtracted. However, these calculations are made not in the air-combat model but in GC and TC, as appropriate.

Aircraft that attack supplies in regions come from IDR aircraft (as discussed in Section H, below).

F.   AIR-TO-AIR AND GROUND-TO-AIR ATTRITION

The air-to-air and ground-to-air attrition processes in IDAGAM I have been described in some detail in Volume 1, and this description will not be repeated here. One important detail not fully described in Volume 1 is the order in which the engagements occur. This ordering is important because the aircraft that emerge from one engagement can be inputs to another engagement, and then the aircraft killed in the first engagement would not be present for the second engagement.

In Figure 4 (below), the ordering of engagements is given for Blue aircraft attacking Red. (The ordering is the same for Red aircraft attacking Blue.) The notation used in that figure

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Ordering	Engagement	Type of Engagement (ℓ,m)
1	$BACE(KBA,IR)_1 \leftrightarrow RACD(KRA,IR)_1$	(1,1)
2	$\left[\sum_{J \in IR} \left(BACA(KBA,J)_1 + BACS(KBA,J)_1 + BACG(KBA,J)_1 \right) \right] \leftrightarrow RACD(KRA,IR)_2$	(1,1)
3	$\left[BACS(KBA,J)_2 + BACG(KBA,J)_2 \right] \leftarrow RSS(J)$	(1,1)
4	$BACS(KBA,J)_2 \rightarrow RSS(J)_1$	(1,1)
5	$BACG(KBA,J)_3 \leftrightarrow RGS(J)_1$	(1,1)
6	$BACA(KBA,J)_2 \leftarrow RSS(J)_1$	(1,1)
7	$BACA(KBA,J)_3 \leftarrow RGS(J)_1$	(1,1)
8	$\left[\begin{array}{l} BAFE(KBA,IR)_1 + BARE(KBA,IR)_1 \\ + \left(\frac{1}{NIR} * BAZE(KBA)_1 \right) \end{array} \right] \leftrightarrow RACD(KRA,IR)_3$	(1,2)
9	$\left[\begin{array}{l} BAFA(KBA,IR)_1 + BAFS(KBA,IR)_1 + BAFG(KBA,IR)_1 \\ + BARA(KBA,IR)_1 + BARS(KBA,IR)_1 + BARG(KBA,IR)_1 \\ + \left(\frac{1}{NIR} * (BAZA(KBA)_1 + BAZA(KBA)_1 + BAZG(KBA)_1) \right) \\ + BAIDR(KBA,IR)_1 \end{array} \right] \leftrightarrow RACD(KRA,IR)_4$	(1,2)
10	$\left[\begin{array}{l} BAFE(KBA,IR)_2 + BARE(KBA,IR)_2 + \left(\frac{1}{NIR} * BAZE(KBA)_2 \right) \\ + BAFA(KBA,IR)_2 + BAFS(KBA,IR)_2 + BAFG(KBA,IR)_2 \\ + BARA(KBA,IR)_2 + BARS(KBA,IR)_2 + BARG(KBA,IR)_2 \\ + \left(\frac{1}{NIR} * (BAZA(KBA)_2 + BAZS(KBA)_2 + BAZG(KBA)_2) \right) \\ + BAIDR(KBA,IR)_2 \end{array} \right] \leftarrow RSS(J)_1$	(1,2)

(continued on next page)

Figure 4.   ORDER OF (AIR AND GROUND)-TO-AIR ENGAGEMENTS (BLUE ATTACKING RED)

Ordering	Engagement	Type of Engagement (ℓ,m)
11	$BAFE(KBA,IR)_3 \leftrightarrow RAFD_1(KRA,IR)$	(2,1)
12	$\left[\begin{array}{l} BAFA(KBA,IR)_3 + BAFS(KBA,IR)_3 \\ + BAFG(KBA,IR)_3 + BAIDR(KBA,IR)_3 \end{array}\right] \leftrightarrow RAFD_2(KRA,IR)$	(2,1)
13	$[BAFS(KBA,IR)_4 + BAFG(KBA,IR)_4] \leftarrow RSFR(IR)$	(2,1)
14	$BAFS(KBA,IR)_4 \rightarrow RSFR(IR)_1$	(2,1)
15	$BAFG(KBA,IR)_5 \leftrightarrow RAGFR(IR)_1$	(2,1)
16	$[BAFA(KBA,IR)_4 + BAIDR(KBA,IR)_4] \leftarrow RSFR(IR)_1$	(2,1)
17a	$BAFA(KBA,IR)_5 \leftarrow RAGFR(IR)_1$	(2,1)
17b	$BAIDR(KBA,IR)_5 \leftarrow \left[\sum_{KRD} RWDR(NKRW-1,KRD,IR) \right]$	(2,1)
18	$\left[BARE(KBA,IR)_3 + \left(\frac{1}{NIR} * BAZE(KBA)_3\right) \right] \leftrightarrow RAFD(KRA,IR)_3$	(2,2)
19	$\left[\begin{array}{l} BARA(KBA,IR)_3 + BARS(KBA,IR)_3 \\ + BARG(KBA,FR)_3 + \left(\frac{1}{NIR} * (BAZA(KBA)_3 \right. \\ \left. + BAZS(KBA)_3 + BAZG(KBA)_3)\right) \end{array}\right] \leftrightarrow RAFD(KRA,IR)_4$	(2,2)
20	$\left[\begin{array}{l} BARE(KBA,IR)_4 + \left(\frac{1}{NIR} * BAZE(KBA)_4\right) \\ + BARA(KBA,IR)_4 + BARS(KBA,IR)_4 \\ + BARG(KBA,IR)_4 + \left(\frac{1}{NIR} * (BAZA(KBA)_4 \right. \\ \left. + BAZS(KBA)_4 + BAZG(KBA)_4)\right) \end{array}\right] \leftarrow RSFR(IR)_1$	(2,2)

Figure 4 (continued)

Ordering	Engagement	Type of Engagement (ℓ, m)
21	$\text{BARE(KBA,IR)}_5 \leftrightarrow \text{RARD}_1\text{(KRA,IR)}$	(3,1)
22	$[\text{BARA(KBA,IR)}_5 + \text{BARS(KBA,IR)}_5 + \text{BARG(KBA,IR)}_5] \leftrightarrow \text{RARD}_2\text{(KRA,IR)}$	(3,1)
23	$[\text{BARS(KBA,IR)}_6 + \text{BARG(KBA,IR)}_6] \leftarrow \text{RSAMRR(IR)}$	(3,1)
24	$\text{BARS(KBA,IR)}_6 \rightarrow \text{RSAMRR(IR)}_1$	(3,1)
25	$\text{BARG(KBA,IR)}_7 \leftrightarrow \text{RAGRR(IR)}_1$	(3,1)
26	$\text{BARA(KBA,IR)}_6 \leftarrow \text{RSAMRR(IR)}_1$	(3,1)
27	$\text{BARA(KBA,IR)}_7 \leftarrow \text{RAGRR(IR)}_1$	(3,1)
28	$[\frac{1}{\text{NIR}} * \text{BAZE(KBA)}_5] \leftrightarrow \text{RARD(KRA,IR)}_3$	(3,2)
29	$[\frac{1}{\text{NIR}} * (\text{BAZA(KBA)}_5 + \text{BAZS(KBA)}_5 + \text{BAZG(KBA)}_5)] \leftrightarrow \text{RARD(KRA,IR)}_4$	(3,2)
30	$\left[\begin{array}{l}\frac{1}{\text{NIR}} * (\text{BAZE(KBA)}_6 + \text{BAZA(KBA)}_6 \\ + \text{BAZS(KBA)}_6 + \text{BAZG(KBA)}_6)\end{array}\right] \leftarrow \text{RSAMRR(IR)}_1$	(3,2)
31	$\text{BAZE(KBA)}_7 \leftrightarrow \text{RAZD(KRA)}_1$	(4,1)
32	$[\text{BAZA(KBA)}_7 + \text{BAZS(KBA)}_7 + \text{BAZG(KBA)}_7] \leftrightarrow \text{RAZD(KRA)}_2$	(4,1)
33	$[\text{BAZS(KBA)}_8 + \text{BAZG(KBA)}_8] \leftarrow \text{RSAMZ}$	(4,1)
34	$\text{BAZS(KBA)}_8 \rightarrow \text{RSAMZ}_1$	(4,1)
35	$\text{BAZG(KBA)}_9 \leftrightarrow \text{RAGZ}_1$	(4,1)
36	$\text{BAZA(KBA)}_8 \leftarrow \text{RSAMZ}_1$	(4,1)
37	$\text{BAZA(KBA)}_9 \leftarrow \text{RAGZ}_1$	(4,1)

Figure 4 (concluded)

is as follows: The variables $BACA(KBA,J)$, $RSS(J)$, etc., have already been defined. The subscripts that appear on these variables indicate the number of times (counting the current one) that those aircraft (or SAMs or AAA) have been targets in an engagement. For example, $BAZA(KBA)_1$ indicates the first time that aircraft on ABA missions to the COMMZ have been shot at by an enemy weapon system, while $BAZA(KBA)_9$ indicates the ninth time these aircraft have been shot at. (The arguments KBA, KRA, J, and IR are carried along for clarity. It should be noted, for example, that $BACE(KBA,IR) \leftrightarrow RACD(KRA,IR)$ means that all the BACE aircraft escorting attackers in region IR engage all the $RACD(KRA,IR)$ aircraft in region IR and that an engagement occurs once for each region IR.)

The arrows between the variables indicate which is the shooter and which is the target. A two-headed arrow means that each weapon is shooting at the other and that the kills are not subtracted until each has shot at the other. A one-headed arrow always points in the direction of the target.

Finally, the column headed "Type of Engagement (ℓ,m)" indicates the location where the engagement is taking place (sector, if $\ell = 1$; forward region, if $\ell = 2$; rear region, if $\ell = 3$; and COMMZ, if $\ell = 4$) and whether the attacker is attempting to "fly by" ($m = 1$) or attack in that area ($m = 2$). The reader is warned that this particular notation is consistent with Volume 1 but that it is not the notation used in the computer program.

Based on these engagements, the number of Blue type-KBA aircraft on CAS missions in sector J that successfully deliver their ordnance is $BACA(KBA,J)_3$; the number on IDR missions in region IR that successfully deliver their ordnance is $BAIDR(KBA,IR)_5$; and the number on ABA missions that successfully deliver their ordnance in forward-region IR, rear-region IR, and the COMMZ is $BAFA(KBA,IR)_5$, $BARA(KBA,IR)_7$, and $BAZA(KBA)_9$, respectively.

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After the aircraft have delivered their ordnance, they have to return to their home airbase. IDAGAM I approximates the attrition that occurs on their return trip by an input percent times the attrition that occurred on the way in. This input percent can depend on the general type of mission--attack (including suppression), escort, or defense--and, for attackers, on the aircraft type. For example, the total number of type-KBA aircraft on ABA missions to the COMMZ that are killed is given by

$$\left(1 + FFBAKH(KBA)\right) * \left(BAZA(KBA) - BAZA(KBA)_9\right) .$$

The number of aircraft killed on each mission is prorated by the number of aircraft sent on that mission from each airbase to determine aircraft losses by home airbase. For example, if there were one Blue region and if the number of type-KBA aircraft sent on ABA missions to the COMMZ from the forward-region airbase, rear-region airbase, and COMMZ airbases were 30, 20, and 10, respectively, and if

$$\left(1 + FFBAKH(KBA)\right) * \left(BAZA(KBA) - BAZA(KBA)_7\right) = 12 ,$$

then 6 type-KBA aircraft on that mission from the forward-region airbase are assumed to have been killed (and 4 are killed from the rear-region airbase and 2 are killed from the COMMZ airbase).

Similar computations are made for Red attacking Blue, and these computations comprise all of parts 3, 4, 5, and 6, and some of part 7 of the air-combat model (i.e., all of AC3, AC4, AC5, AC6, and some of AC7).

G. ATTRITION OF AIRCRAFT ON THE GROUND

The calculation of attrition of aircraft on the ground to ABA missions follows the general principles stated in Volume 1. However, there are two features that apply only to these attrition processes and not to air-to-air or ground-to-air attrition.

First, the attacking aircraft might be able to make several passes, each at different aircraft on the ground. And on each

pass, the attacking aircraft might be able to shoot at several aircraft on the ground. All other things being equal, an aircraft that can make several passes or that can shoot at several aircraft on each pass is more effective than an aircraft that can make only one pass and that can shoot at only one aircraft on the ground during that pass. Theoretically, this increased effectiveness could be considered in determining the effectiveness parameters ($D_{\ell m}^{st}$ and K_{ij}^{st}, in the notation of Volume 1), if the multiple-engagement binomial equation or either Lanchester equation is used to calculate attrition. But if the single-engagement binomial equation or an exponential approximation to it is being used, than this capability cannot correctly be included in the effectiveness parameter and must be modeled directly. In IDAGAM I, this capability is considered directly for all six attrition equations by multiplying the number of successful (type-KBA or type-KRA) aircraft on ABA missions by an input (PBAAGM(KBA) for Blue attackers, and PRAAGM(KRA) for Red attackers), and using the product as the number of attackers.

Second, not all the aircraft based on an airbase will be there when that airbase is attacked. Since some number of those aircraft will be out flying their own missions, they will not be on the airbase and will not be targets for the attackers. This reduction in targets for ABA aircraft is considered in IDAGAM I by multiplying the number of (type-KBA or type-KRA) aircraft stationed on the base by [1 - PDBANG(KBA)] for Blue aircraft and [1 - PDRANG(KRA)] for Red aircraft--i.e., PDBANG(KBA) of the Blue aircraft on each airbase are assumed not to be on their airbase when that airbase is attacked (and the same for Red).

The calculation of attrition of aircraft on the ground is made in part 7 of the air-combat model (AC7).

H. ATTRITION OF DIVISIONS IN RESERVE

The equations used to calculate the attrition of divisions in reserve by aircraft on IDR missions are given (in Volume 1) in algebraic notation. The basic reason for using these equations is to be consistent with the equations used in the ground-combat model for computing attrition in combat sectors, and those equations are explained in detail in Volume 1. Instead of repeating those parts of Volume 1 here, we will give the correspondence between the algebraic notation used in Volume 1 and the mnemonic notation used in the computer program. This correspondence is given in Figure 5.

Blue Attacking Red		Red Attacking Blue	
Algebraic Notation	Corresponding Mnemonic Notation	Algebraic Notation	Corresponding Mnemonic Notation
B_c^{ar}	BAIDRT(KBA,IR)	R_c^{ar}	RAIDRT(KRA,IB)
L_{cm}^{bad}	BAMNLA(KBA,KBAM)	L_{cm}^{rad}	RAMNLA(KRA,KRAM)
A_{mj}^{*baa}/R_j^*	SABMAR(KBAM,KRW)	A_{mj}^{*raa}/B_j^*	SARMAB(KRAM,KBW)
K_{mj}^{bar}	BAMKAR(KBAM,KRW)	K_{mj}^{rar}	RAMKAB(KRAM,KBA)
D_{mj}^{baa}	RPWLDM(KRW,KBAM)	D_{mj}^{raa}	BPWLDM(KBW,KRAM)
R_j	$\sum_{KRD}$ RWDR(KRW,KRD,IR)	B_j	$\sum_{KBD}$ BWDR(KBW,KBD,IB)
$\dot{R}_j$	RWLR(KRW,IR)	$\dot{B}_j$	BWLR(KBW,IR)
$\dot{R}_0$	RCR(IR)	$\dot{B}_0$	BCR(IB)

Figure 5. NOTATION USED FOR COMPUTING ATTRITION TO DIVISIONS IN RESERVE

Chapter III

THE GROUND-COMBAT MODEL

In Volume 1, the structure of the ground-combat model was described in terms of the following 11 steps:

(1) Set sector index equal to 1.

(2) Degrade forces in the sector (if they are not balanced).

(3) Determine sector attacker.

(4) Compute attrition in the sector.

(5) Prorate weapon losses to divisions, and prorate casualties to personnel types within divisions.

(6) Compute FEBA movement in the sector.

(7) Compute the number of supplies lost and supplies consumed in the sector.

(8) Compute the number of recovered and repairable weapons in the sector.

(9) Compute the number of nonbattle casualties in the sector.

(10) Test sector index. If all sectors have been considered, go to Step 11; otherwise, increment the sector index and return to Step 2.

(11) Adjust the FEBA for front-to-flank considerations across sectors.

Of these steps, Steps 1, 5, 7, 8, 9, and 10 are straightforward and can be easily understood in the computer program with the help of Volume 2 (the definitions of the variables). These steps will not be discussed in this volume.

Steps 4 and 6 are discussed in some detail in Volume 1. Rather than repeating those discussions, we will give the correspondence between the algebraic notation used in Volume 1 and the mnemonic notation used in the computer program (as we did for attrition to divisions in reserve in the air-combat model).

Steps 2, 3, and 11 will be discussed in detail in this chapter. Accordingly, the five sections of this chapter correspond in order to Steps 2, 3, 4, 6, and 11 of the ground-combat model discussed in Chapter II, Section C, in Volume 1.

A. DEGRADATION OF UNBALANCED FORCES

IDAGAM I allows a force in a sector to be degraded if it becomes too unbalanced. For example, a force consisting only of artillery should not, logically, be very effective, because it could easily be overrun by enemy armor and infantry; whereas a force consisting of fewer artillery (but with some armor and infantry) could be quite effective, because the armor and infantry, in addition to providing their own firepower, help protect the artillery. IDAGAM I uses the structure described in this section to consider this type of interaction between weapons on the same side.

To consider this type of interaction, IDAGAM I assumes that each type of weapon on each side can be put into one of three groups. Weapons in the first group have the inherent capability to protect themselves. In addition, these weapons can provide protection for weapons in the other two groups. Weapons in the second group cannot protect themselves without the assistance of weapons in the first group. But if, for example, there are enough weapons in the first group to protect 10 weapons in the second group, then these 10 weapons can protect other weapons in the second group. All protected weapons in the second group can provide protection for weapons in the third group. Weapons in the third group cannot protect themselves, nor can they protect any other weapon.

The input IPGBW(KBW) determines which protection group Blue type-KBW weapons are in (whether IPGBW(KBW) equals 1, 2, or 3 depends on whether type-KBW weapons are in the first, second, or third group)--and IPGRW(KRW) does the same for Red.

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The input BWGPG(KKBW,KBW) determines how many type-KBW weapons each type-KKBW weapon can protect. For example, suppose there are three types of Blue weapons: small arms, tanks, and artillery. Suppose that the user decides that small arms belong in the first group, artillery belongs in the third group, and (due to the threat of enemy hand-held antitank weapons) tanks belong in the second group. Suppose also that the user decides that 2 small arms can protect a tank, that each tank protected by small arms can protect 0.5 of another tank, and that it takes 40 small arms or 6 tanks to protect each artillery piece. Then BWGPG(1,1), BWGPG(2,1), BWGPG(3,1), BWGPG(3,2), and BWGPG(3,3) need not be defined (the user can enter 0 in these positions); and

$$BWGPG(1,2) = 2 ,$$
$$BWGPG(1,3) = 40 ,$$
$$BWGPG(2,2) = 0.5 ,$$
$$BWGPG(2,3) = 6 .$$

Now suppose that, through attrition, the Blue force in a sector had 400 small arms, 400 tanks, and 100 artillery pieces in combat. Then IDAGAM I would play that all 400 small arms were fully effective and that these small arms can protect 200 tanks. These 200 tanks can protect another 100 tanks--giving a total of 300 protected tanks. The 400 small arms can protect 10 artillery pieces, while the 300 tanks can protect 50 artillery pieces--giving a total of 60 protected artillery pieces.

In IDAGAM I, the unprotected weapons (in this example, 100 tanks and 40 artillery pieces) are assumed to be withdrawn from combat for that day. They cannot cause casualties or contribute to their side's effectiveness; and, conversely, they cannot be fired on or destroyed by the enemy. At the end of the day, these weapons are returned to the Blue force, so that, if Blue received replacements, these weapons could be effective the next day. Accordingly, in this example, the Blue force

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would fight as if it had 400 small arms, 300 tanks, and 60 artillery pieces.

The point of these calculations is not that weapons are either fully protected and fully effective or not protected and withdrawn from battle; the point is that the extremes where a force becomes too unbalanced can be roughly estimated— and that the model should have some way of incorporating these rough estimates, so as not to assign full effectiveness to an unbalanced force.

B. DETERMINATION OF SECTOR ATTACKER

In IDAGAM I, there is a theater attacker and sector attackers for each sector; and the sector attackers need not all be the same as the theater attacker. For example, Red may be on attack in the theater; but, in a particular sector, Blue may be much stronger than Red and may be on attack in that sector. The way that the model determines who is on attack in each sector is as follows:

First, the model computes the ground and air value that each side would have it it were on attack and if it were on defense—i.e., the model computes the following variables:

Blue		Red	
Volume 1 Notation	Computer Program Notation	Volume 1 Notation	Computer Program Notation
V_k^{bga}	VBGAS	V_k^{rga}	VRGAS
V_k^{bgd}	VBGDS	V_k^{rgd}	VRGDS
V^{baa}	VBAAS	V^{raa}	VRAAS
V^{bad}	VBADS	V^{rad}	VRADS

We will comment on how these variables are computed in Section C, below.

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Now suppose that Red is the theater attacker (the situation is symmetric if Blue is the theater attacker). Then the model will test to see whether Red can attack in the sector under consideration. Let FRRB be the force ratio redefined as follows:

$$FRRB = \frac{VRGAS + VRAAS}{VBGDS + VBADS} \cdot$$

Let ISMA(J) be an index giving the sectors of main attack for Red according to the following:

$$ISMA(J) = \begin{cases} 1, & \text{if sector J is a sector} \\ & \text{of main attack for Red;} \\ 0, & \text{otherwise} . \end{cases}$$

(ISMA(J) is computed in TCTZ and TC2.) If ISMA(J) = 1 or if sector J is next to a sector that is constrained by front-to-flank ratio, then Red will attack in sector J if FRRB $\geq$ FRRAT(KP) and Red will not attack if FRRB < FRRAT(KP) in sector J, where KP is the posture that Red would be in if Red were to attack. If ISMA(J) = 0 and sector J is not next to a sector that is constrained by front-to-flank ratio, then Red will attack in sector J if both FRRB $\geq$ FRRAT(KP) and FRRB $\geq$ FRRASA(J,KP) and Red will not attack otherwise, where KP is as defined above.

If Red attacks, then Blue must defend. If Red does not attack, then Blue can either attack or not attack. (Red is given the "first choice," because Red is the theater attacker.) If neither side attacks, then a holding posture exists in the sector.

If Red does not attack, then Blue will attack in the sector if both FRBR $\geq$ FRBAT(KP) and FRBR $\geq$ FRBASD(J,KP), where KP is the posture that Blue would be in if Blue were to attack, and where FRBR is as follows:

$$FRBR = \frac{VBGAS + VBAAS}{VRGDS + VRADS} \cdot$$

This procedure defines the variable ISA, where

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$$\text{ISA} = \begin{cases} 1, & \text{if Red attacks in the sector;} \\ -1, & \text{if Blue attacks in the sector;} \\ 0, & \text{if neither side attacks in the sector (holding} \\ & \text{posture).} \end{cases}$$

The basic idea here is that there is a minimum force ratio (FRBAT(KP) and FRRAT(KP)) below which a side will not attack under any circumstances. Above that minimum force ratio, if the side is on attack in the theater and if the sector under consideration is a sector of main attack or is constraining a sector of main attack due to front-to-flank ratio, then the side attacks. If the side is on attack in the theater and the sector is not a sector of main attack (and is not constraining one), or if the side is on defense in the theater, then the side will attack only if the force ratio also exceeds another input (FRBASA(J,KP) or FRBASD(J,KP) for Blue; and FRRASA(J,KP) or FRRASD(J,KP) for Red) that depends on the sector, the type of posture, and whether the side in question is on attack or on defense in the theater.

C. ATTRITION

The previous section indicates one reason that the order in which the computer program does calculations in the ground-combat model is not the same as the order in which they are described in Volume 1. The computer program must calculate VBGAS, VBAAS, VBGDS, and VBADS, and the corresponding variables for Red, in order to determine who is on attack in the sector. Once this determination is made, the rest of the attrition calculations are made, using the "attack" or "defense" values as appropriate.

A more significant reason why the order of calculation is different is as follows: The ground-attrition process in IDAGAM I was not developed in one step. Instead, it was developed by improving upon the ground-attrition equations programmed in GACAM II, examining the result and improving on it, and so on. This step-by-step development led to the ground-attrition process

in IDAGAM I, and this process can be explained in these terms
(i.e., it can be explained by first explaining the GACAM II
attrition process and then explaining the improvements that
led to IDAGAM I). If these explanations were presented here,
then the order of the computations in IDAGAM I could be given
in those terms. However, to do so would be a waste of the
reader's time, because there is a more straightforward way
(the way it is explained in Volume 1) to explain the ground-
attrition process in IDAGAM I. Further, someone interested in
a detailed knowledge of the order of computation can obtain it
by reading through the IDAGAM I computer program, which is rela-
tively easy to do because the computer program was designed to
be readable with the help of the definitions of the variables
(in Volume 2).

Thus, rather than attempting to explain GACAM II and then
the improvements that led to IDAGAM I, we refer to the explana-
tion of the ground-combat-attrition process given in Volume 1;
and we give in Figure 6 (below) the correspondence between the
algebraic notation used in Volume 1 and the mnemonic notation
used in the computer program.

When considering Figure 6, it should be noted that B_j^* and
R_j^* are defined in Volume 1 as the number of Blue weapons and
Red weapons in a standard force, while PBWSF(KBW) and PRWSF(KRW)
are defined in Volume 2 as percentages of weapons in a standard
force. This distinction is not important, since allocation of
fire is sensitive only to the relative number of weapons of each
type, not the absolute number. Also, while SABWDR(KBW,KRW) and
the other allocation parameters are input, these parameters are
recalculated in TCTZ according to the correspondence given in
Figure 6. Further details on these parameters are given in the
discussion of TCTZ in Chapter V (below).

The variables given in Figure 6 are those used if Red is
on attack (analogous variables are used if Blue is on attack).

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Algebraic Notation	Corresponding Mnemonic Notation	Algebraic Notation	Corresponding Mnemonic Notation
$\dot{B}_j$	BWLS(KBW)	A_{ij}^{*bgd}/R_j^*	SABWDR(KBW,KRW)
$\dot{B}_j^p$	$\left[\sum\limits_{KRW} RWS(KRW) * PRAKBP(KP,KRW,KBW)\right.$	P_{ijk}^{bgd}	VBWDRP(KP,KBW,KRW)
	$\left. + \sum\limits_{KRA} RAS(KRA) * PRAAKB(KRA,KBW)\right]$	L_{cm}^{bad}	BAMNLD(KBA,KBAM)
c_j^b	BPWLD(KBW)	A_{mj}^{*bad}/R_j^*	SABMDR(KBAM,KRW)
$\dot{B}_0$	BCS(J)	P_{mj}^{bad}	VBAMDR(KBAM,KRW)
$\dot{R}_j$	RWLS(KRW)	R_i	RWS(KRW)
$\dot{R}_j^p$	$\left[\sum\limits_{KBW} BWS(KBW) * PBDKRP(KP,KBW,KRW)\right.$	R_i^*	PRWSF(KRW)
	$\left. + \sum\limits_{KBA} BAS(KBA) * PBADKR(KBA,KRW)\right]$	R_c^a	RAS(KRA)
		A_{ij}^{*rga}/B_j^*	SARWAB(KRW,KBW)
c_j^r	RPWLA(KRW)	P_{ijk}^{rga}	VRWABP(KP,KRW,KBW)
$\dot{R}_0$	RCS(J)	L_{cm}^{raa}	RAMNLA(KRA,KRAM)
$\dot{B}_i$	BWS(KBW)	A_{mj}^{*raa}/B_j^*	SARMAR(KRAM,KBW)
B_i^*	PBWSF(KBW)	P_{mj}^{raa}	VRAMAB(KRAM,KBW)
B_c^a	BAS(KBA)	

Figure 6.   NOTATION FOR COMPUTING ATTRITION IN COMBAT SECTORS
(ASSUMING RED IS ON ATTACK)

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Algebraic Notation	Corresponding Mnemonic Notation	Algebraic Notation	Corresponding Mnemonic Notation
D_{ij}^{bgd}	RPWLAW(KRW,KBW)	B_{0d}	$\sum_{KBP}$ BPDS(KBP,KBD,J)
D_{mj}^{bad}	RPWLAM(KRW,KBAM)	B_{0d}^{t}	$\sum_{KBP}$ TPBD(KBP,KBD) * NBDS(KBD,J)
D_{ij}^{rga}	BPWLDW(KBW,KRW)	N_{d}^{b}	NBDS(KBD,J)
D_{mj}^{raa}	BPWŁDM(KBW,KRAM)	$f_{d}^{bed}(\cdot)$	BDEF(·)
Q_{ij}^{bgd}	BWS(KBW) * PBDKRP(KP,KBW,KRW)	G_{d}^{bd}	BRRDD(KBD)
$\sum_m Q_{mj}^{bad}$	$\sum_{KBA}$ (BAS(KBA) * PBADKR(KBA,KRW))	L_{d}^{b}	BALBD(KBD)
Q_{ij}^{rga}	RWS(KRW) * PRAKBP(KP,KRW,KBW)	$f_{k}^{bcd}(\cdot)$	PCBDF(·)
$\sum_m Q_{mj}^{raa}$	$\sum_{KRA}$ (RAS(KRA) * PRAAKB(KRA,KBW))	R^{s}	RGSS(J)
B^{s}	BGSS(J)	S_{i}^{cr}	RPCRWS(KRW)
S_{i}^{cb}	BPCRWS(KBW)	S_{0}^{cr}	RPCRPS(KRP)
S_{0}^{cb}	BPCRPS(KBP)	$f^{sr}(\cdot)$	SEFRF(·)
$f^{sb}(\cdot)$	SEFBF(·)	R_{id}	RWDS(KRW,KRD,J)
B_{id}	BWDS(KBW,KBD,J)	R_{id}^{t}	TWRD(KRW,KRD) * NRDS(KRD,J)
B_{id}^{t}	TWBD(KBW,KBD) * NBDS(KBD,J)	R_{0d}	$\sum_{KRP}$ RPDS(KRP,KRD,J)

Figure 6 (continued)

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Algebraic Notation	Corresponding Mnemonic Notation	Algebraic Notation	Corresponding Mnemonic Notation
R_{0d}^{t}	$\sum_{KRP}$ TPRD(KRP,KRD) * NRDS(KRD,J)	B_{d}^{fsy}	YBPP = YBPPDS(KBD,J)
N_{d}^{r}	NRDS(KRD,J)	E_{d}^{bpy}	YBDEDS(KBD,J)
$f_{d}^{rea}(\cdot)$	RAFF(·)	E_{d}^{bpoy}	YBDPE
G_{d}^{ra}	RRRDA(KRD)	G_{d}^{bdy}	YBPRD
L_{d}^{r}	BALRD(KRD)	E_{d}^{bp}	BDPEDS
$f_{k}^{rca}(\cdot)$	PCRAF(·)	V_{kd}^{bpd}	BDPEDS * TBWVDS
D^{shb}	DSHB	V_{k}^{bgd}	VBGDS
E^{sb}	SEFB	V^{bad}	VBADS
D^{shr}	DSHR	V_{kd}^{rwa}	RWVDS
E^{sr}	SEFR	V_{kd}^{rpa}	RAPEDS * TRWVDS
V_{ik}^{lbwd}	VIBWDP(KBW,KP)	V_{k}^{rga}	VRGAS
V_{kd}^{bwd}	BWVDS	V^{raa}	VRAAS
V_{kd}^{tbwd}	TBWVDS	F^{cd}	FRCD
B_{d}^{fs}	BPP	F^{ca}	FRCA
E_{d}^{bpo}	BDPE		(concluded on next page)

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Figure 6 (continued)

Algebraic Notation	Corresponding Mnemonic Notation	Algebraic Notation	Corresponding Mnemonic Notation
$f^{bch}(\cdot)$	PCBHF($\cdot$)	i_b	IWUCE
p^{cd}	PCBS(J)	v_{ik}^{lrwa}	VIRWAP(KRW,KP)
p^{ca}	PCRS(J)	v_c^{lbad}	VIBAD(KBA)
E^{sm}	PPESE	v_c^{lraa}	VIRAA(KBA)
K_{ij}^{bw}	PBDKRP(KP,KBW,KRW)	w_i^{bgd}	LVBGD(KBW)
K_{cj}^{ba}	PBADKR(KBA,KRW)	w_m^{bad}	LVBAD(KBA)
K_{ij}^{rw}	PRAKBP(KP,KRW,KBW)	w_i^{rga}	LVRGA(KRA)
K_{cj}^{ra}	PRAAKB(KRA,KBW)	w_m^{raa}	LVRAA(KRA)
$\overline{K}^{bw}$	R		
$\sqrt{\lambda}$	ALAM (in GC)		

Figure 6 (concluded)

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The order in which the variables are listed is the order in which the algebraic variables are introduced in Volume 1.

D. FEBA MOVEMENT

Since the FEBA-movement calculations in the ground-combat model are described in detail in Volume 1, we will give only the correspondence between the algebraic notation used in Volume 1 and the mnemonic notation used in the computer program. This correspondence is given in Figure 7, where the variables given are those used if Red is on attack (analogous variables are used if Blue is on attack). The order in which the variables are listed is the order in which the algebraic variables are introduced in Volume 1.

If the movement of the FEBA (as computed by the method described in Volume 1) causes the FEBA to remain in the same interval throughout the day, then the FEBA movement (DFEBA) is applied to the FEBA position at the beginning of the day to give the FEBA position at the end of the day. However, if this movement causes the FEBA to reach an interval boundary (i.e., if DFEBA > FEIR(J) - FEBA(J)), then the following calculations are made:

If the posture that Red would be in when Red enters the next interval (KPRAN(J)) is attack of a defensive position, then the FEBA movement for that day stops at the interval boundary, and Red starts at the beginning of that next interval at the beginning of the next day. The reason for playing movement this way is as follows: The logic for the reserve policy (i.e., how many divisions to have in reserve and how many to have on the front) depends on the posture of the attacker and defender. The basic idea is to allow the defender to be able to commit a higher percentage of his divisions when he is attempting to defend a defensive position than when he is in another posture. If the attacker were allowed to continue fighting when he meets a defensive position during a day, he might be able to get

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Algebraic Notation	Corresponding Mnemonic Notation
M^{cmr}	MCRM
M^r_{dkt}	RMFDPT(KRD,KP,KT)
S^r_d	PNRD(KRD)
$f^r_{kt}(\cdot)$	RFMF($\cdot$)
W^{ra}	RMFAS(J)
W	WIDS(J)
M_{kt}	RMFS
F_1	DFEBA1
$\overline{F}_{21}$	DFBA2A
$\overline{F}_{22}$	DFBA2C
$\overline{F}_{23}$	DFBA2B
ρ	PDFBA2
F_2	DFEBA2
F_3	DFEBA3
F	DFEBA

Figure 7. NOTATION FOR COMPUTING FEBA MOVEMENT
(ASSUMING RED IS ON ATTACK)

through a significant portion of that position before the end of the day, and the defender could not reinforce that position until the end of the day. (IDAGAM I does not allow the defender to "look ahead" to see that the attacker is approaching a defensive position and to reposition his forces accordingly.) By requiring the attacker to stop at the boundary and begin the next day at the beginning of the defensive position, the defender can reposition his forces overnight to make the planned use of the defensive position. Since IDAGAM I plays that all forces can move to their destination overnight, this structure is equivalent to allowing the defender to move his forces into position in advance of the attack on a defensive position.

If the user of IDAGAM I is making all divisional moves by input and bypassing the reserve-policy logic in TC, then it is not necessary to stop the attacker in the middle of the day at the beginning of a defensive position. In this case, the user can modify GC by removing statement number 23002 and the two statements preceding that statement.[1] These removals will allow the attacker to begin to attack a defensive position in the middle of a day.

If the posture that Red would be in when Red enters the next interval is not the attack of a defensive position (or if the three statements mentioned above have been removed), then the calculation for the movement of the FEBA for the part of the day after the FEBA crosses an interval boundary is based on posture, terrain, and width of the sectors in the next interval.

IDAGAM I can consider only one such change in intervals. That is, if an interval were so shallow that it could be crossed in a half a day by a particular force, and if that force were only a quarter day's movement away from the interval boundary at the

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[1]If these statements are removed, then the interval preceding an interval containing a defensive position should be sufficiently deep that it cannot be traversed in one day. The reason for this depth requirement is explained at the end of this section.

beginning of the day, IDAGAM I would base movement for the first quarter of the day on the geographical properties of the current interval and would base movement for the remaining three quarters of the day on the geographical properties of the next interval, even though the FEBA would be in a third interval for the last quarter of the day. This capability to consider only one change in intervals is not felt to be a significant limitation of IDAGAM I because, unless the user plays many shallow intervals, this event is unlikely to occur; and, when it does occur, it will induce a very small error in calculating the position of the FEBA.

Before concluding the discussion of FEBA-movement calculations, we should note that the deeper the interval containing a prepared defense is, the longer it will take (and the more costly it will be) for the attacker to penetrate it. Likewise, the deeper the interval containing a minefield is, the more effective it will be. Thus, prepared defenses of various qualities and minefields of various effectiveness can be played in IDAGAM I simply by adjusting the depth of the intervals containing these characteristics. In particular, the depth of these intervals should reflect not the physical depth on the battlefield but rather the effectiveness of the barriers contained in them.

E.   FRONT-TO-FLANK CONSIDERATIONS

The FEBA-movement calculations are made once for each sector, and each calculation is independent of the FEBA position in the other sectors. Step 11 of the ground-combat model adjusts the resulting FEBA positions to account for front-to-flank considerations.[1] This section discusses how these adjustments are calculated.

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[1] In Volume 1, front-to-flank considerations were discussed in conjunction with notional minor sectors to determine the movement of the FEBA with a sector. That discussion should not be confused with the discussion here, which concerns the relationship between the FEBA positions in adjoining sectors and the exposed flanks between sectors.

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A basic problem in considering front-to-flank constraints is that both sides can be constrained simultaneously. In this situation, either the defender could withdraw or the attacker's movement could be stopped. Such a situation could look like the following:
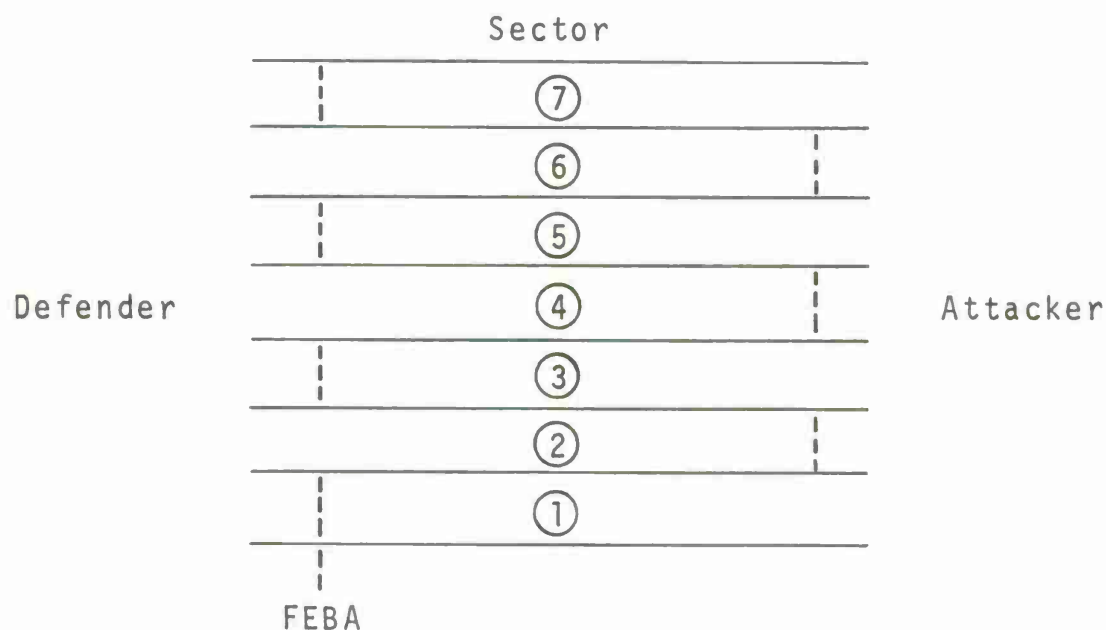
Sector

This situation might occur, for example, if the attacker were to concentrate his forces in every other sector.

An alternative case occurs if the attacker concentrates his forces in a few sectors, say sectors 3 and 6, which could result in the following situation:
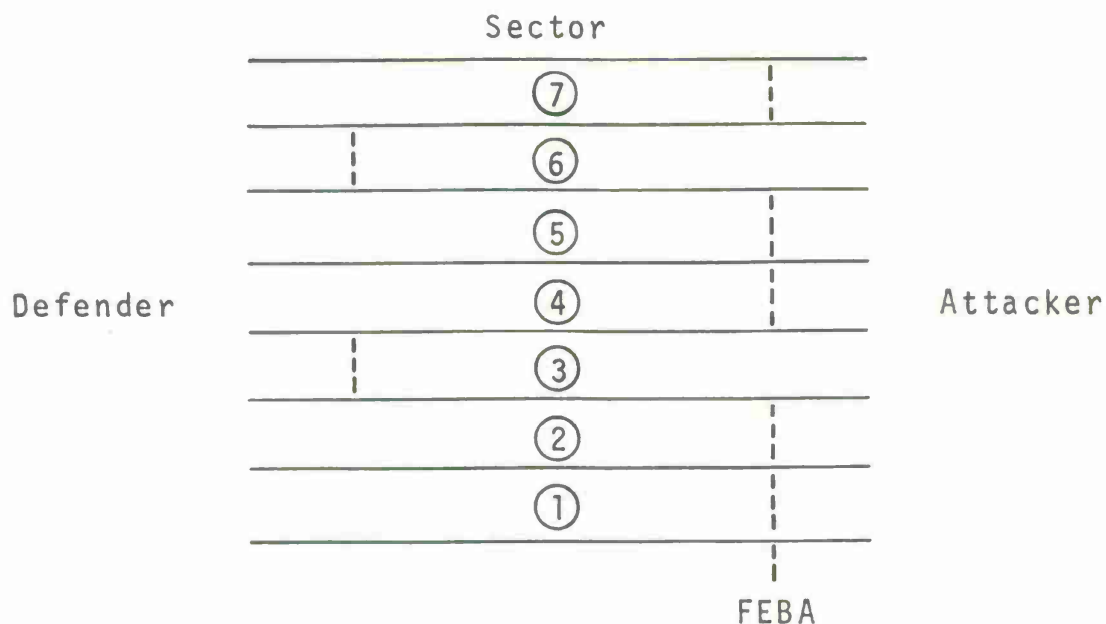
Sector

In this second case, it seems reasonable that the attacker would be stopped in sectors 3 and 6, and would have to advance in sectors 2, 4, 5, and 7 in order to continue moving in sectors 3 and 6 (as opposed to the defender's being forced to withdraw in sectors 1, 2, 4, 5, and 7).

This second case seems more likely than the first (and it is typical of what would occur if the method of computing the sector of main attack is to select the sector with best FEBA position--e.g., MCSMAR = 1 for Red on attack).

Based on this reasoning, IDAGAM I first determines if the attacker is constrained by front-to-flank considerations. If the attacker can hold the positions he achieved according to the FEBA-movement calculation, he does. If the attacker cannot hold these positions, then he is forced to withdraw until the FEBA positions are such that he can hold them. Once this withdrawal is made, then the defender is considered. And if he can hold the positions he finds himself in, fine; otherwise, he must withdraw to positions he can hold.

It should be noted that this order of calculation is arbitrary, in the sense that the defender could first be forced to withdraw before the attacker is considered. And it is clearly advantageous to either side to have the other side withdraw first. But based on the situations described above, it seems generally more reasonable to require that the attacker be able to hold his position before requiring the defender to withdraw, which is what IDAGAM I does.

Of course, if it is desired not to constrain the attacker or the defender (or both) by front-to-flank considerations, then the appropriate inputs (FFRRS(J) for Red on attack, FFRBDS(J) for Blue on defense, etc.) can be set equal to zero.

Before discussing the calculations, one feature and two assumptions of IDAGAM I should be discussed. The feature is

as follows: The model considers an input "edge factor" to determine the amount of the exposed sector flanks to be considered in these calculations. For example, if a particular interval in a particular sector had a neutral country or an impassable mountain range on one of its flanks, then a side might not care whether that flank was exposed or not. In this case, the user could input 0.0 for the edge factor for that flank. The model considers the product of the length of the side's exposed flank and the edge factor. So, if the edge factor were 0.0, the model would consider the length of the exposed flank to be 0.0, rather than the actual exposed length. If the edge factor were 1.0, then the model would consider the actual length of the exposed flank. The input variable for the edge factor is EFHIS(INTS,J), which gives the edge factor in interval INTS in sector J between sector J and sector J+1. In TC2, the model determines the intervals that contain the FEBA in sectors J and J-1 and sets

$$EDGEH(J) = EFHIS(INTS,J)$$

and

$$EDGEL(J) = EFHIS(INTS,J-1) .$$

Edge factors apply only to the boundaries between sectors. They do not apply to the "lower" boundary of sector 1 or the "higher" boundary of section NJ. The first of the two assumptions mentioned above is that neither the lower flank of sector 1 nor the higher flank of sector NJ is considered in determining the amount of exposed flank for either the attacker or defender. In essence, the model assumes that

$$EDGEL(1) = EDGEH(NJ) = 0.0 .$$

The second assumption applies to the attacker only. This assumption is that the attacker's advance in a sector will not be stopped if the FEBA of one of its adjoining sectors is further advanced (if the edge factor between these sectors is not

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0.0). For example, suppose that the attacker has acceptable
exposed flanks on either side of sector J-1 but that between
sector J and sector J+1 the exposed flank is very large (i.e.,
sector J-1 is slightly ahead of sector J, which is far ahead
of sector J+1; and sector J-1 is "stable"). And suppose the
edge factor between sectors J-1 and J is not 0.0. Then if
the attacker were to withdraw in sector J to reduce the exposed
flank between sectors J and J+1, he would be increasing his
exposed flank between sectors J-1 and J. Rather than allow
this type of withdrawal or require the attacker to withdraw
in both sectors J-1 and J, the model assumes that the attacker
does not have to withdraw in either sector.

With these assumptions, consider the following situation:
Suppose that Red is on attack, and let

FFRRS(J) = the minimum front-to-flank ratio that Red will
accept on attack in sector J;

WIDS(J) = the current width of sector J;

FLANKL = the length of the exposed left flank for Red
in sector J (this cannot be less than zero);

FLANKR = the length of the exposed right flank for Red
in sector J (this cannot be less than zero);

EDGEL = the current lower (left) edge factor;

EDGEH = the current higher (right) edge factor; and

FEBAA = the distance that Red must withdraw in sector
J to read the minimum front-to-flank ratio.

A picture, assuming J ≠ 1 and J ≠ NJ, would look like the
following:

```
       Sector
              ┌─────────────────────────────────────────────┐
       J-1    │              FLANKR                          │
              │        ┌──────────────────────┐              │
              │        │          ┌─ (FLANKR - FEBAA) ─┐     │
 Blue    J    │ WIDS(J)│ ◄─FEBAA─►│                    │     │ Red
              │        │          └─ (FLANKL - FEBAA) ─┐     │
              │        └──────────────────────────────┘     │
       J+1    │                  FLANKL                      │
              └─────────────────────────────────────────────┘
                                                    FEBA
```

Assume $EDGEL(J) \neq 0.0$ and $EDGEH(J) \neq 0.0$. If $FLANKL = 0.0$ or if $FLANKR = 0.0$ or if

$$FFRRS(J) \leq WIDS(J) / \left(FLANKL * EDGEL(J) + FLANKR * EDGEH(J)\right)/2 \ ,$$

then Red is not constrained by front-to-flank considerations in sector J and so Red achieves the full FEBA advance as determined by the FEBA-movement calculations. If

$$FFRRS(J) > WIDS(J) / \left(FLANKL * EDGEL(J) + FLANKR * EDGEH(J)\right)/2 \ ,$$

and if both FLANKL and FLANKR are greater than zero, then Red does not achieve the full FEBA advance. If Red were forced to withdraw a distance of FEBAA in sector J, then his exposed flanks would be equal to FLANKL - FEBAA and FLANKR - FEBAA. If this results in exactly a front-to-flank ratio of FFRRS(J), then

$$FFRRS(J) = WIDS(J) / \left((FLANKL - FEBAA) * EDGEL(J) + (FLANKR - FEBAA) * EDGEH(J)\right)/2 \ .$$

Solving for FEBAA gives FEBAA =

$$\left((FLANKL * EDGEL) + (FLANKR * EDGEH) - (2 * WIDS(J) / FFRRS(J))\right) / \left(EDGEL(J) + EDGEH(J)\right) \ .$$

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Then FEBAA is applied to FEBA(J), to give new FEBA positions in sector J, according to the formula

$$FEBA(J) \leftarrow FEBA(J) - MIN \{FEBAA, FLANKL, FLANKR\} .$$

Similar calculations are made if $J = 1$ or $J = NJ$ or if $EDGEL(J) = 0.0$ or $EDGEH(J) = 0.0$, except that only one flank is considered.

Unlike the attacker, the defender can be forced to withdraw if one of his exposed flanks is too big, regardless of the other flank. For each sector, first one flank is tested, then the other is tested, then the sum of the exposed flanks is tested. If the exposed flank is too long in any of these tests, the defender is forced to withdraw.

Chapter IV

THE THEATER-CONTROL MODEL

The parts of the theater-control model explained in Section D of Chapter II of Volume 1 are the only parts of that model that require detailed explanations. The other parts are simple and straightforward and can easily be followed in the computer program with the help of Volume 2 (the definitions of the variables).

Accordingly, the rest of this chapter will consist only of three figures and the following explanations: In Figure 8 is given the correspondence between the algebraic notation introduced in Section D.2 of Chapter II of Volume 1 concerning personnel and weapon replacement and the mnemonic notation used by the computer program. The variables are listed in the order in which the algebraic variables are introduced in that section of Volume 1.

In Figure 9 is given the correspondence between the algebraic notation introduced in Section D.3 of Chapter II of Volume 1 concerning reinforcements and withdrawals of divisions and the mnemonic notation used by the computer program. The variables are listed in the order in which the algebraic variables are introduced in that section of Volume 1.

In Figure 10 is given the correspondence between the algebraic notation introduced in Section D.4 of Chapter II of Volume 1 concerning supplies and the mnemonic notation used by the computer program. The variables are listed in the order in which the algebraic variables are introduced in that section of Volume 1. As described in Volume 1, supplies can be destroyed in three places: in sectors, en route from regions to sectors,

and in regions. The destruction of supplies in sectors is com-
puted in GC, and both destruction of supplies en route from
sectors to regions and the destruction of supplies in regions
are computed in TCl. The discussion in Section D.4.6 of
Chapter II of Volume 1 considers all three cases, and all the
variables introduced there are listed in Figure 10--no matter
whether they are used in GC or in TCl.

Algebraic Notation[a]	Corresponding Mnemonic Notation[a]
B_{id}^{r}	$\begin{cases} \text{BRWDS(KBW,KBD,J)} & \text{for divisions in sectors} \\ \text{BRWDR(KBW,KBD,IB)} & \text{for divisions in regions} \end{cases}$
B_{0d}^{tr}	$\begin{cases} \text{BRDS(KBD,J)}^{b} & \text{for divisions in sectors} \\ \text{BRDR(KBD,J)}^{b} & \text{for divisions in regions} \end{cases}$
P_{i}^{bgn}	VIBWMN(KBW)[c]
P_{i}^{bgx}	VIBWMX(KBW)[c]
B_{0d}^{r}	$\begin{cases} \text{BRDS(KBD,J)}^{b} & \text{for divisions in sectors} \\ \text{BRDR(KBD,J)}^{b} & \text{for divisions in regions} \end{cases}$

[a]Note that B_{id}, B_{id}^{t}, N_{d}^{b}, P_{ijk}^{bga}, and P_{ijk}^{bgd} have the same corresponding mnemonic notation as given in Figure 6.

[b]BRDS(KBD,J) and BRDR(KBD,IB) are the trial number of personnel replacements as calculated in section 60 (statements 6000-6055) of TC1. Then, in section 135 (statements 13500-13581) of TC1, BRDS(KBD,J) and BRDR(KBD,IB) are recomputed to give the actual number of personnel replacements.

[c]These variables are calculated one way for one purpose in the statements preceding statement 3001 in section 30 of TC1; they are calculated a different way for the purpose of calculating actual personnel replacements in the statement preceding statement 13502 in section 135 of TC1. P_{i}^{bgn} and P_{i}^{bgx} correspond to VIBWMN(KBW) and VIBWMX(KBW) as calculated in section 135 of TC1.

Figure 8. SOME NOTATIONS USED FOR COMPUTING PERSONNEL AND WEAPON REPLACEMENTS FOR BLUE

Algebraic Notation	Corresponding Mnemonic Notation	Algebraic Notation	Corresponding Mnemonic Notation
F_1^{bra}	MBRFBA	F_{1k}^{brd}	FRBDP(KP)
L_1^{bra}	0.0^a	L_{1k}^{brd}	RLBDP(KP)
F_2^{bra}	FRBAFF	F_2^{brd}	MRBFBD
L_2^{bra}	RLBAFF	L_2^{brd}	RLBDFM
F_{3k}^{bra}	FRBAP(KP)	F_2^{bwd}	FRBWDN
L_{3k}^{bra}	RLBAP(KP)	$L_2^{bwd} = L_2^{brd}$	RLBDFM
F_{1k}^{bwa}	BFWFSP(J,KP)	F	FR
L_1^{bwa}	1.0^a	L	RL
F_3^{bwa}	FRBWAN	S_d^{ba}	PSBWDA(KBD)
$L_{3k}^{bwa} = L_{3k}^{bra}$	RLBAP(KP)	S_d^{bd}	PSBWDD(KBD)

[a]These are not really variables; as explained in Volume 1, their values are fixed (to be 0.0 or 1.0, respectively) by the computer program.

Figure 9.   NOTATION USED FOR COMPUTING REINFORCEMENTS AND WITHDRAWALS OF DIVISIONS FOR BLUE

Algebraic Notation	Corresponding Mnemonic Notation	Algebraic Notation	Corresponding Mnemonic Notation
$B^{ss}(J)$	BGSS(J)	$B_c^{l}(J)$	BAS(KBA,J)
$B^{srp}(I)$	BGSR(IB)	F_c^{bsi}	FBACSI(KBA)
$B^{srd}(I)$	BGSRUR(IB)	$B_c^{si}(J)$	FBACSI(KBA) * BAS(KBA,J)[b]
B^{szr}	BGSZ	U_c^{b}	RSBASI(KBA)
B^{szd}	BGSZUZ	$V^{b}(J)$	PBSUIS(J)
$R^{ss}(J)$	RGSS(J)	$R^{srs}(J)$	RGSSS(J)[c]
$R^{srp}(I)$	RGSR(IR)	$\dot{R}^{srs}(J)$	CRSLI[d]
$R^{srd}(I)$	RGSRUR(IR)	F_c^{bir}	FBAISR(KBA)
R^{szp}	RGSZ	$F_c^{bir} B_c^{7}(IR)$	BAISR(KBA,IR)
R^{szd}	RGSZUZ	U_c^{br}	RSBASR(KBA)
$X_c = (1 - P_c)Y_c$	RSLBAC(KBA)[a]		

[a] This variable is used in GC only, as it applies only to destruction of supplies in sectors.

[b] The computer program does not use this formula, but uses one equivalent to it.

[c] This correspondence holds if Red has enough supplies in the region pool to fill all demands; otherwise, $R^{srs}(J)$ corresponds to [RGSSS(J)/RSD] * RGSR(IR).

[d] IDAGAM I does not define a separate variable that corresponds to $\dot{R}^{srs}(J)$. CRSLI is the cumulative number of supplies lost--the sum over J and over all days of the war so far of $\dot{R}^{srs}(J)$. It is the increment that is added to CRSLI in TC2 that corresponds directly to $\dot{R}^{srs}(J)$.

Figure 10. NOTATION USED FOR LOCATION, INTERDICTION, AND DESTRUCTION OF SUPPLIES (BLUE INTERDICTION RED SUPPLIES)

Chapter V

THEATER CONTROL AT TIME ZERO

The TCTZ subroutine (Theater Control at Time Zero) con-
sists of nine sections (in addition to the one section that
returns control to the main program). Each of these sections
will be discussed briefly below. In general, there are two
reasons for making calculations in TCTZ: First, some calcula-
tions need be made only once per run of IDAGAM I; since TCTZ is
called only once, these calculations are made in TCTZ. Second,
some calculations need to be made every time before AC and GC
are run. For all but the first day, these calculations are
made in TC2. But since TC2 is not called before the first day
of the war, these calculations are made in TCTZ for the first
day.

Section 10 of TCTZ computes the lowest-numbered sector in
each region. This number is always one more than the highest-
numbered sector in the next-lowest-numbered region (or 1, for
the first region). Since this calculation needs to be done
only once, it is done in TCTZ.

Section 15 of TCTZ initializes FEBA(J).

Section 20 of TCTZ computes which sectors are to be sectors
of main attack if Red is the theater attacker (and Section 30
does the same if Blue is the theater attacker). This computa-
tion is made for day 1 in TCTZ and for each succeeding day of
the war in TC2.

Section 40 computes geographical quantities based on the
current position of the FEBA. This computation is also made for
day 1 in TCTZ and for each succeeding day of the war in TC2.

Section 45 computes the value of Blue weapons against a standard Red force and the value of Red weapons against a standard Blue force, and it adjusts the standard allocations.

The reason for computing the value against a standard opponent's force is as follows: In the computation of attrition in GC, the value of each weapon is computed, giving consideration to the mix of weapons it is facing. However, in AC, TC1, and TC2, the model makes allocations based, in part, on weapon values. For example, in AC the model determines into which sectors the CAS aircraft attack; in TC1 the model determines how many weapon replacements of one type can substitute for a weapon replacement of another type; and in TC2 the model determines reinforcements and withdrawals of divisions. The computation in TC1 is based on the weapon values of the side doing the replacing, and the other two computations are based on the weapon values of both sides. It would be unrealistic and undesirable to make these calculations based on the actual mix of enemy weapons. It would be unrealistic because a side might not know the actual mix of enemy weapons. (In GC, while the side might not know the actual mix of enemy weapons, the actual effectiveness of the side's weapons would depend on that mix.) Accordingly, if the side does not know the actual mix of enemy weapons, it cannot make allocations based on values computed from that mix and so would have to compute values based on a standard enemy mix of weapons. Second, it would be unreasonable to base allocations on the actual mix of enemy weapons (even if it were known what this mix was) because the enemy, through replacements, reinforcements, withdrawals, etc., could change his mix before the next day's battle. Thus, it seems generally more reasonable to base these calculations on a standard enemy mix of weapons.

Since the calculations of weapon values against a standard enemy force need be made only once, they are made in TCTZ.

The formula for the calculation by weapon types of potential Red weapons lost is given in Section C.2.b of Chapter II of Volume 1 as

$$R_j^p = \sum_i B_i \left(\frac{A_{ij}^{*bgd} R_j / R_j^*}{\sum_{j'} A_{ij'}^{*bgd} R_{j'} / R_{j'}^*} \right) P_{ijk}^{bgd}$$

$$+ \sum_c B_c^a \left(\sum_m L_{cm}^{bad} \left(\frac{A_{mj}^{*bad} R_j / R_j^*}{\sum_{j'} A_{mj'}^{*bad} R_{j'} / R_{j'}^*} \right) P_{mj}^{bad} \right) .$$

Note that the terms A_{ij}^{*bgd}, A_{mj}^{*bad}, and R_j^* never appear other than in the ratios A_{ij}^{*bgd}/R_j^* and A_{mj}^{*bad}/R_j^*. In fact, the allocation variables (A_{ij}^{*bgd} and A_{mj}^{*bad} for Blue on defense, and the corresponding variables for Blue on attack and for Red on attack and defense) and the standard force variables (R_j^* and B_j^*) never appear other than in these types of ratios after TCTZ. Since the attrition calculations use only these ratios, and since the ratios are independent of the actual number of weapons on each side, these ratios are computed once in TCTZ for use in the appropriate attrition equations on each day of the war.

Section 50 computes the order of Red divisions according to TOE weapon value against a standard Blue force (and Section 60 does the same for Blue divisions). The reason that this computation is done is as follows: As described in Section D.3, Chapter II, Volume 1, when a side is determining which divisions to reinforce with or to withdraw, that side is attempting to reach a certain reserve level or force ratio. For example, suppose a side is moving reinforcement divisions forward and wants to have 25 percent of its divisions, weighted according to weapon value, in reserve. Suppose that the side has four divisions in reserve with TOE weapon values of 65, 60, 50, and 40, and that

the side has four divisions, with a total TOE weapon value of 185, already committed. Then IDAGAM I will start with the biggest division in reserve and test it. Since, in this case, the division with the weapon value of 65 can be moved without going below 25 percent in reserve, it is moved. Then the division with the weapon value of 60 is tested. Since moving it would bring the reserve level below 25 percent, it is not moved. Similarly, the division with the weapon value of 50 is not moved; but the division with the weapon value of 40 is moved. This movement results in a reserve level of 27.5 percent. The point here is that divisions are not fractionalized in order to achieve a reserve level of exactly 25 percent, nor is a "knapsack" problem solved to reach as close as possible to 25 percent (in the example, 26.25 percent could have been achieved by moving the two divisions with weapon values of 60 and 50). The method used is to work down from the biggest division to the smallest division, which requires computing the order of the divisions according to their TOE weapon value. Since this calculation need be made only once, it is made in TCTZ.

Finally, Section 70 initializes various working variables. Since this initialization needs to be done only once, it is done in TCTZ.

Chapter VI

GEOGRAPHY

The purpose of this chapter is to give an example of how
to construct the geographical inputs for IDAGAM I.

Suppose that IDAGAM I is being used to model combat in an
area whose geography is given by Figure 11. Suppose further
that Red is attacking (from right to left) and that there are
three avenues of attack (sectors), the first being separated
from the second by the forest, mountains, and short ridge line,
and the second being separated from the third by the long ridge
line.

Suppose that Blue has prepared a defensive position along
the rivers and that the defensive positions in sectors 2 and 3
are three times as good as the defensive position in sector 1.
In addition, suppose that Blue has sown a minefield to the right
of the river in sectors 2 and 3. Finally, suppose that Red has
prepared a defensive position along its side of the FEBA. These
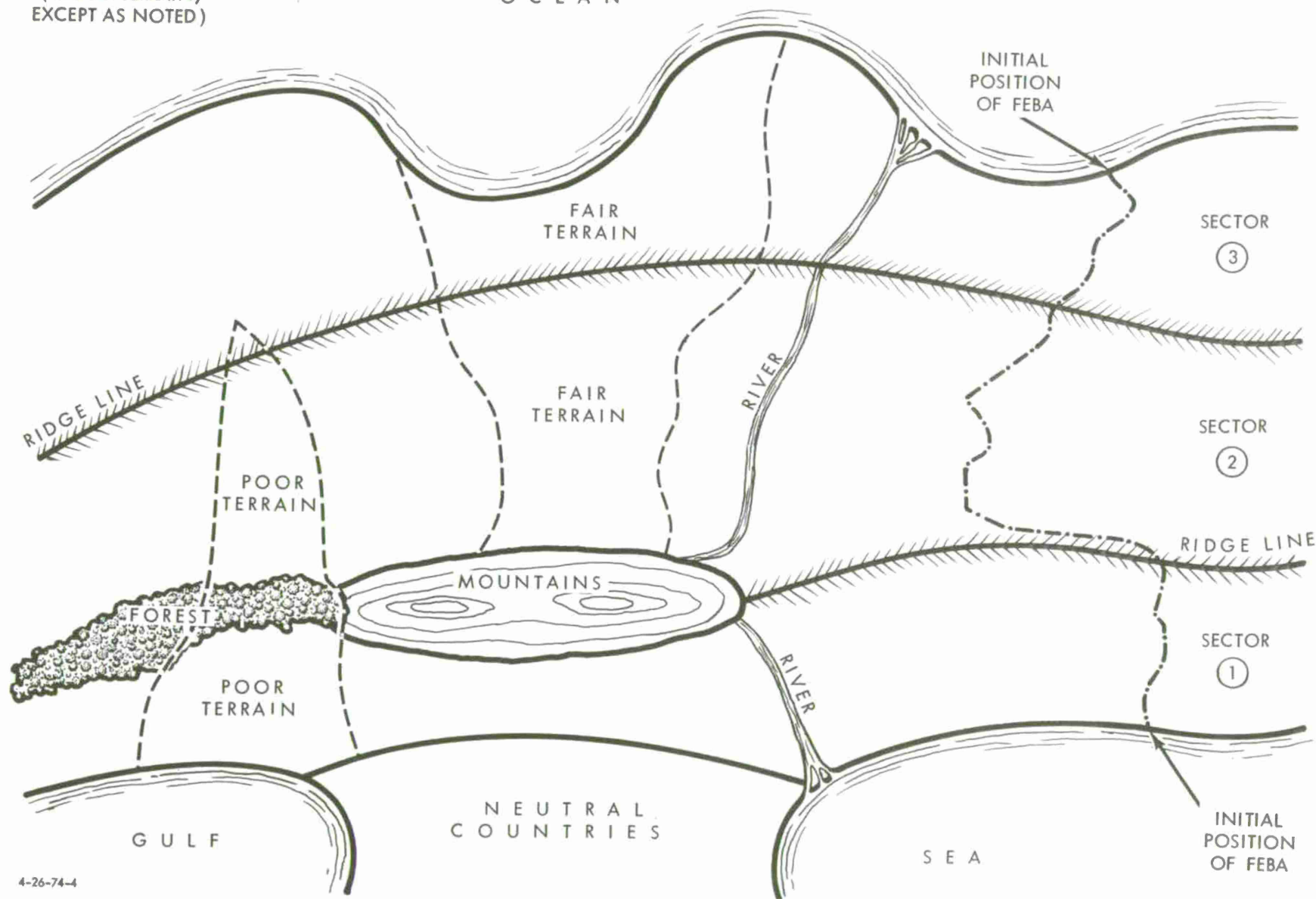defensive positions and minefields are shown in Figure 12.

The first step in converting Figure 12 to input data for
IDAGAM I is to divide each sector into intervals of constant
width, terrain, posture (defensive position, minefield, or
normal attack-delay), and edge factor (between the sector in
question and the next-highest-numbered sector).[1]

---

[1]For this example, we will suppose that all edge factors are
1.0, except where sectors 1 and 2 are separated by mountains.
Suppose that the mountains are practically impassable, so that
the appropriate edge factor is 0.0 for that part of the
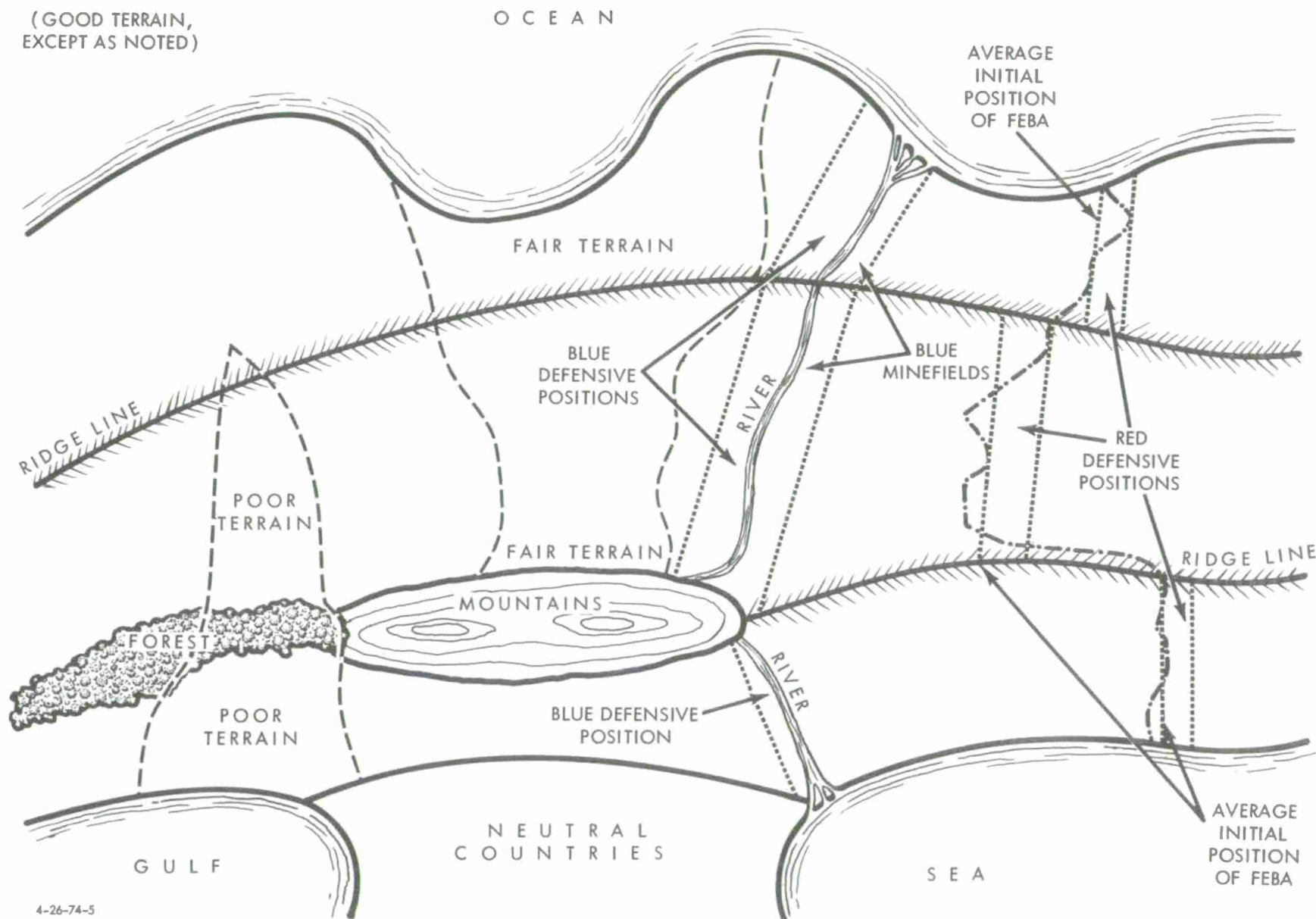boundary between sectors 1 and 2.

Figure 11. EXAMPLE OF GEOGRAPHY

(GOOD TERRAIN, EXCEPT AS NOTED)

OCEAN

INITIAL POSITION OF FEBA

FAIR TERRAIN

SECTOR ③

RIDGE LINE

FAIR TERRAIN

RIVER

SECTOR ②

POOR TERRAIN

RIDGE LINE

MOUNTAINS

FOREST

POOR TERRAIN

RIVER

SECTOR ①

POOR TERRAIN

INITIAL POSITION OF FEBA

GULF

NEUTRAL COUNTRIES

SEA

4-26-74-4

82

(GOOD TERRAIN,
EXCEPT AS NOTED)

OCEAN

AVERAGE
INITIAL
POSITION
OF FEBA

FAIR TERRAIN

RIDGE LINE

BLUE
DEFENSIVE
POSITIONS

BLUE
MINEFIELDS

RIVER

RED
DEFENSIVE
POSITIONS

POOR
TERRAIN

FAIR TERRAIN

RIDGE LINE

MOUNTAINS

FOREST

POOR
TERRAIN

BLUE DEFENSIVE
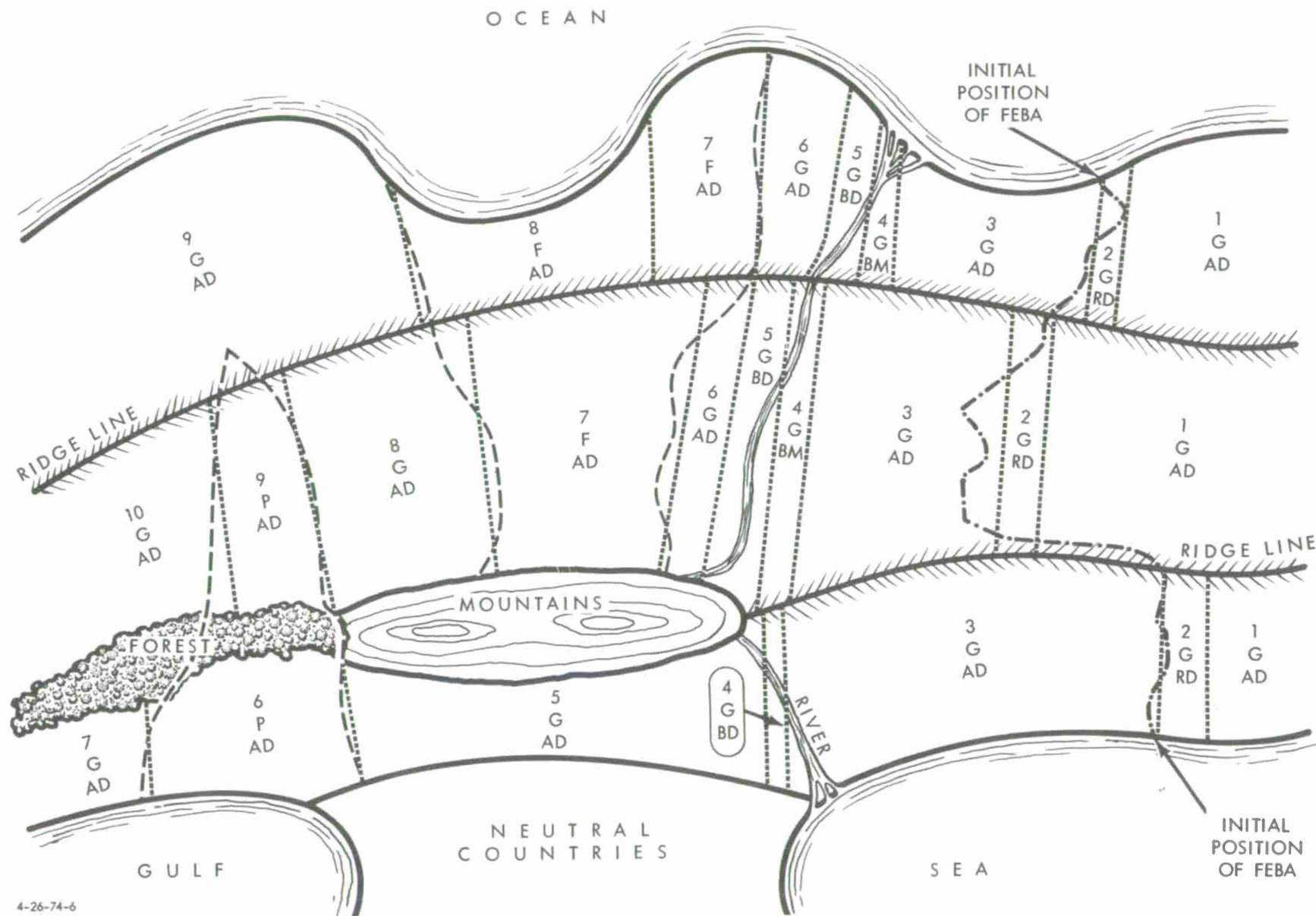POSITION

RIVER

GULF

NEUTRAL
COUNTRIES

SEA

AVERAGE
INITIAL
POSITION
OF FEBA

4-26-74-5

Figure 12.   EXAMPLE OF DEFENSIVE POSITIONS AND MINEFIELDS

The intervals should be bounded by straight lines, where these straight lines should be the average of what would have been an irregular boundary for the interval. Further, these straight lines should be perpendicular to the axis of attack through the sector. For example, since the true initial position of the FEBA is not a straight line across the sectors, we have approximated it in Figure 12 by an average initial FEBA position that is a straight line within each sector and is roughly perpendicular to the sector boundaries.

Figure 13 is based on Figure 12, with dotted straight lines imposed to smooth out irregular interval boundaries. In each interval is a number, which gives the number of that interval in that sector; a letter (G, F, or P), which denotes whether the terrain is good, fair, or poor; and a pair of letters (BM, BD, RD, or AD), which denotes whether the posture is determined by the presence of a Blue minefield, a Blue defensive position, a Red defensive position, or whether combat would be that of a normal attack-delay situation in that interval. (In this example, we are assuming that Red has no minefields; but IDAGAM I can play Red minefields if desired.)

As shown in Figure 13, intervals 7 and 8 in sector 3 have the same terrain and posture situation (F,AD), but two intervals are required because of the significant variation in the width of sector 3 in that area.

The only geographical data not given in Figure 13 are the average length and width of each interval. Suppose these average lengths and widths are as given in Figure 14. Note in Figure 14 that the width of interval 5 in sector 2 (and of interval 5 in sector 3) is three times that of interval 4 in sector 1. This difference in width is because we have assumed that the Blue defensive positions in sectors 2 and 3 are three times better than the Blue defensive position in sector 1.
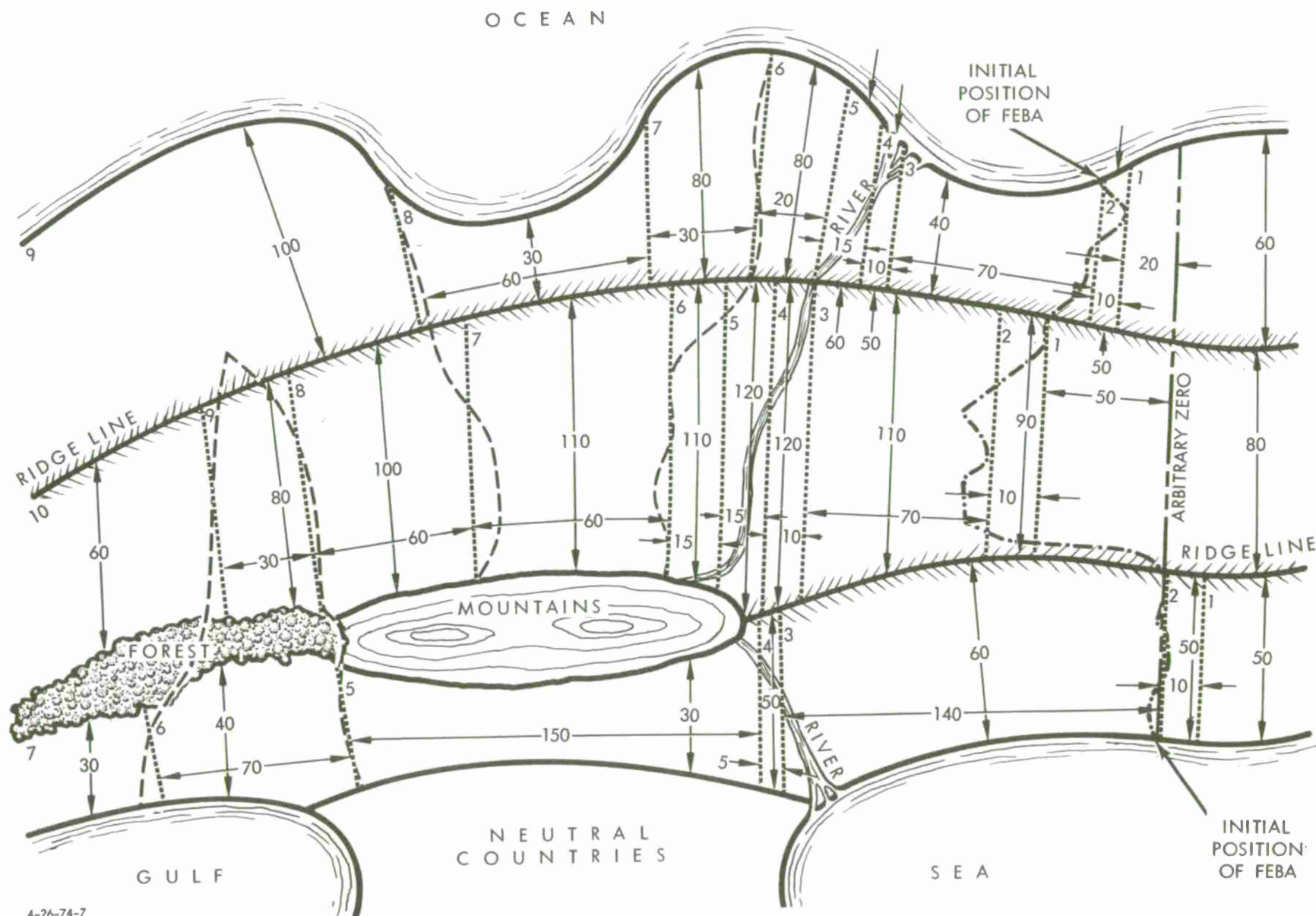
Figure 13. EXAMPLE OF INTERVAL BOUNDARIES

Figure 14.   EXAMPLE OF INTERVAL LENGTHS AND WIDTHS

To enter the data concerning the lengths of the sectors into the model (as well as to identify the FEBA positions on each day of the war), some arbitrary zero line running across the width of the theater must be selected. As shown in Figure 14, we have selected the initial FEBA position in sector 1 as the arbitrary zero line for this example.

Based on Figures 13 and 14, the data given in Figure 15 should be entered into IDAGAM I (assuming that, for terrain, 1 denotes good terrain; 2, fair; and 3, poor). Note that, for posture, 1 must denote a normal attack-delay posture, 2 must denote the attack of a defensive position, 3 must denote the breakthrough of a defensive position (since the model automatically calculates when a side has broken through a defensive position, 3 should never be input as a value for KPBAIS or KPRAIS), and 4 must denote an attack through a minefield.
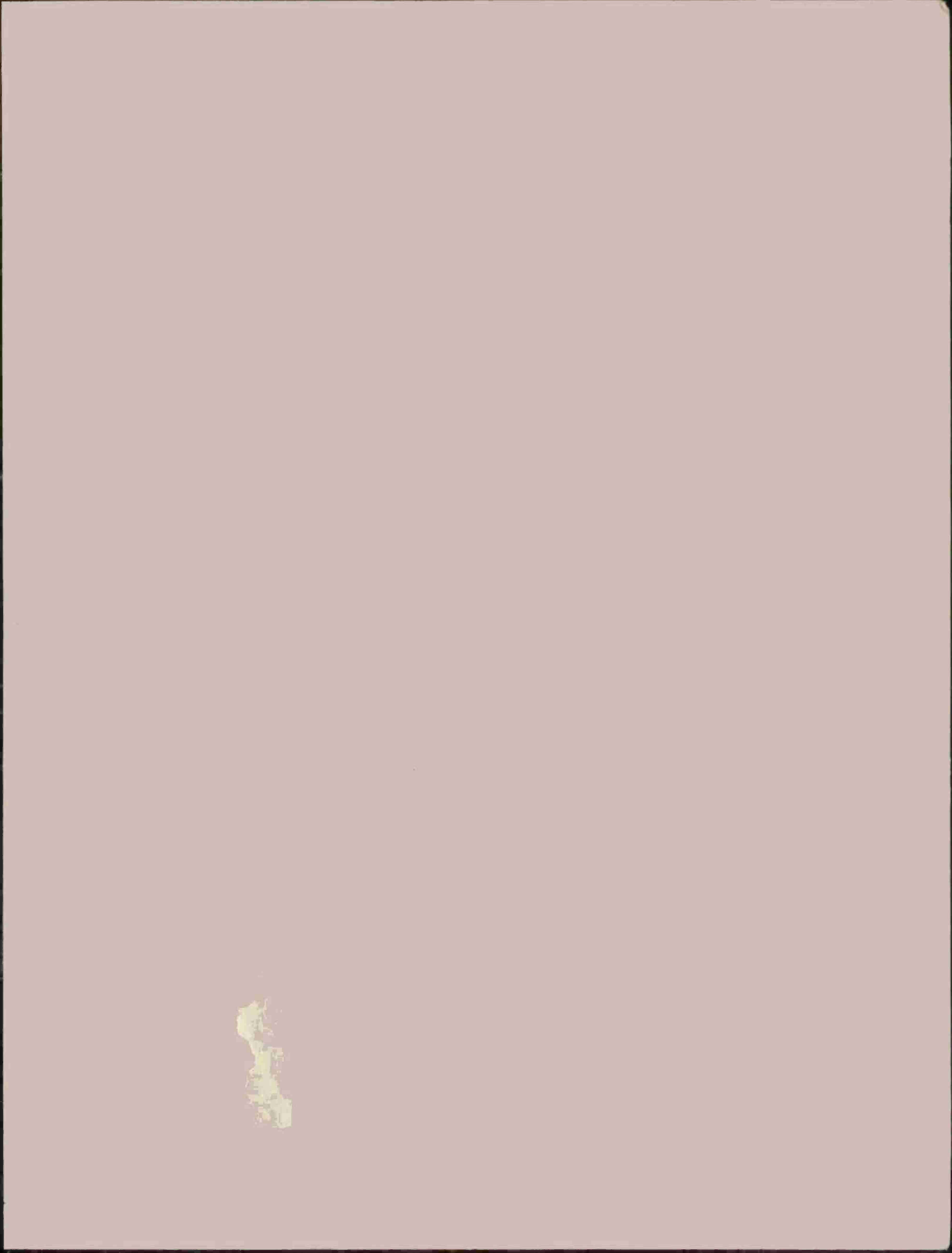
```
2305 NIMAX
        10

2310 NINTS(J)
        7            10             9

2320 BNDIS(INTS,J)
      -10.0          50.0          20.0
        0.0          60.0          30.0
      140.0         130.0         100.0
      145.0         140.0         110.0
      295.0         155.0         125.0
      365.0         170.0         145.0
        0.0         230.0         175.0
        0.0         290.0         235.0
        0.0         320.0           0.0
        0.0           0.0           0.0

2330 KTERIS(INTS,J)
          1             1             1
          1             1             1
          1             1             1
          1             1             1
          1             1             1
          3             1             1
          1             2             2
          0             1             2
          0             3             1
          0             1             0

2340 KPBAIS(INTS,J)
          1             1             1
          2             2             2
          1             1             1
          1             1             1
          1             1             1
          1             1             1
          1             1             1
          0             1             1
          0             1             1
          0             1             0

          (concluded on next page)
```

Figure 15.   EXAMPLE OF
              GEOGRAPHICAL INPUTS

```
2350 KPRAIS(INTS,J)
        1           1           1
        1           1           1
        1           1           1
        2           4           4
        1           2           2
        1           1           1
        1           1           1
        0           1           1
        0           1           1
        0           1           0

2360 WIDIS(INTS,J)
     50.0        80.0        60.0
     50.0        90.0        50.0
     60.0       110.0        40.0
     50.0       120.0        50.0
     30.0       120.0        60.0
     40.0       110.0        80.0
     30.0       110.0        80.0
      0.0       100.0        30.0
      0.0        80.0       100.0
      0.0        60.0         0.0

2370 EFHIS(INTS,J)
      1.0         1.0         0.0
      1.0         1.0         0.0
      1.0         1.0         0.0
      1.0         1.0         0.0
      0.0         1.0         0.0
      1.0         1.0         0.0
      1.0         1.0         0.0
      0.0         1.0         0.0
      0.0         1.0         0.0
      0.0         1.0         0.0
```

Figure 15 (concluded)